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Our December 2016 issue will be published on Thursday 3 November 2016, see page 72 for details.



Quasar Electronics Limited
PO Box 6935, Bishops Cleeve
CM23 4WP, United Kingdom
Tel: 01279 467799
Fax: 01279 267799
E-mail: sales@quasarelectronics.co.uk
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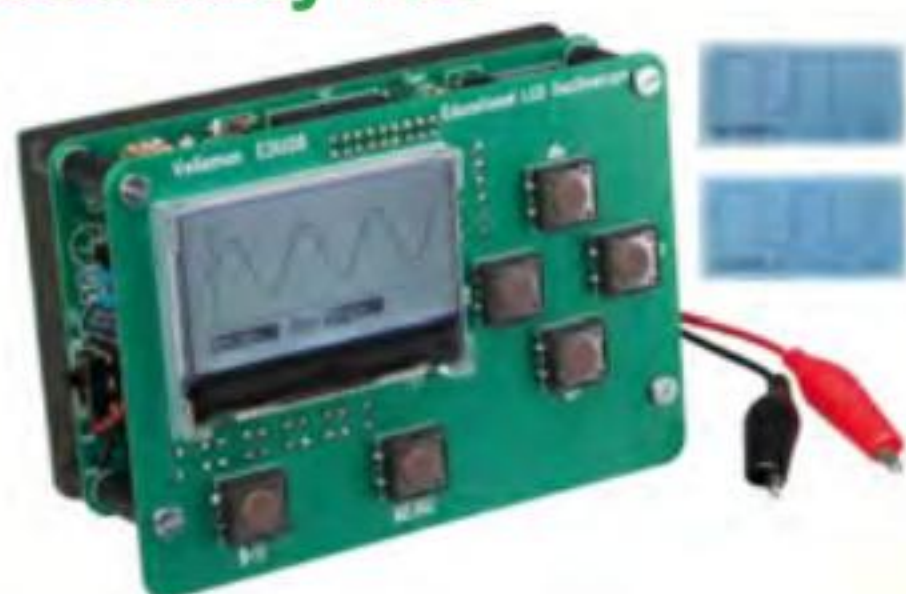
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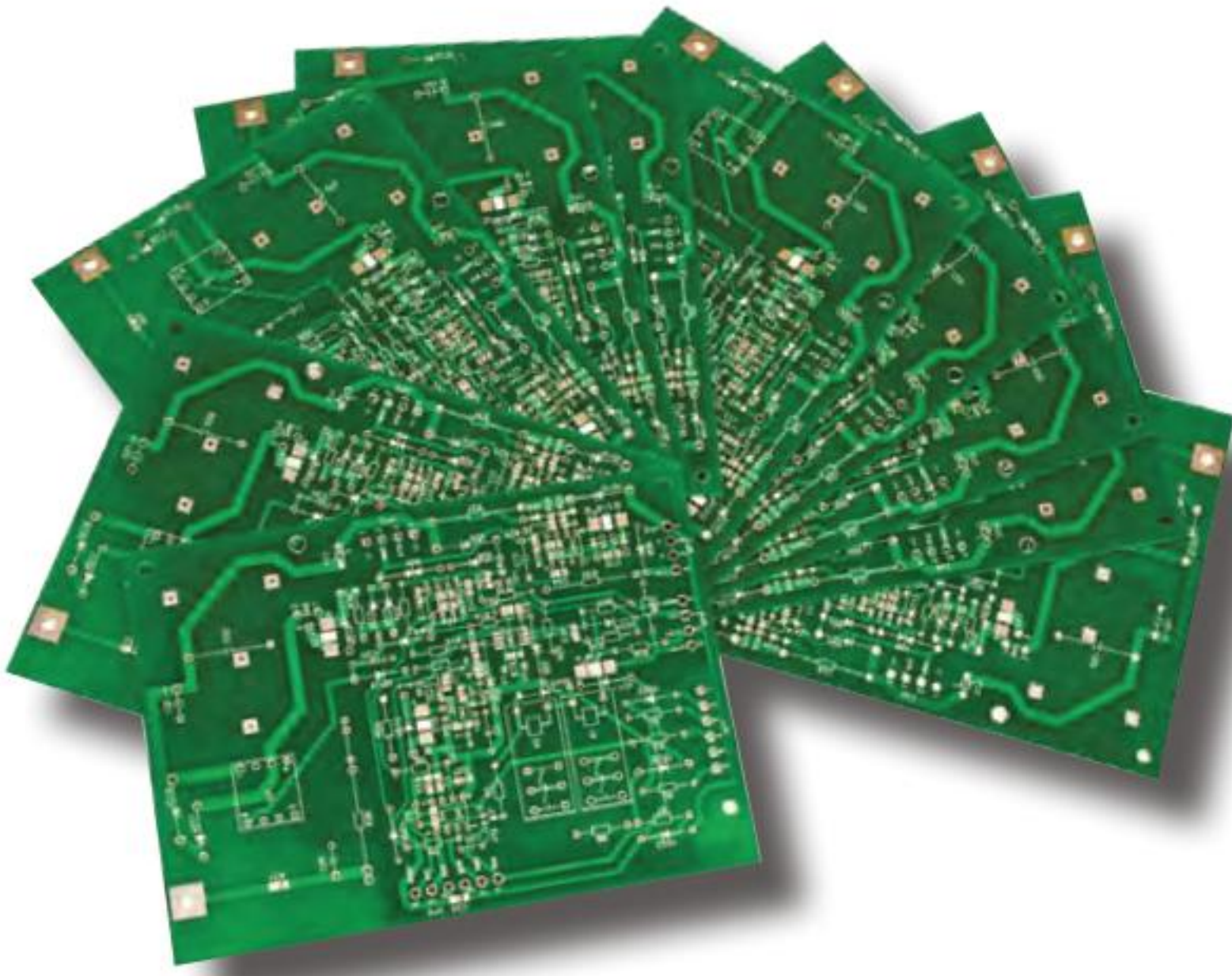
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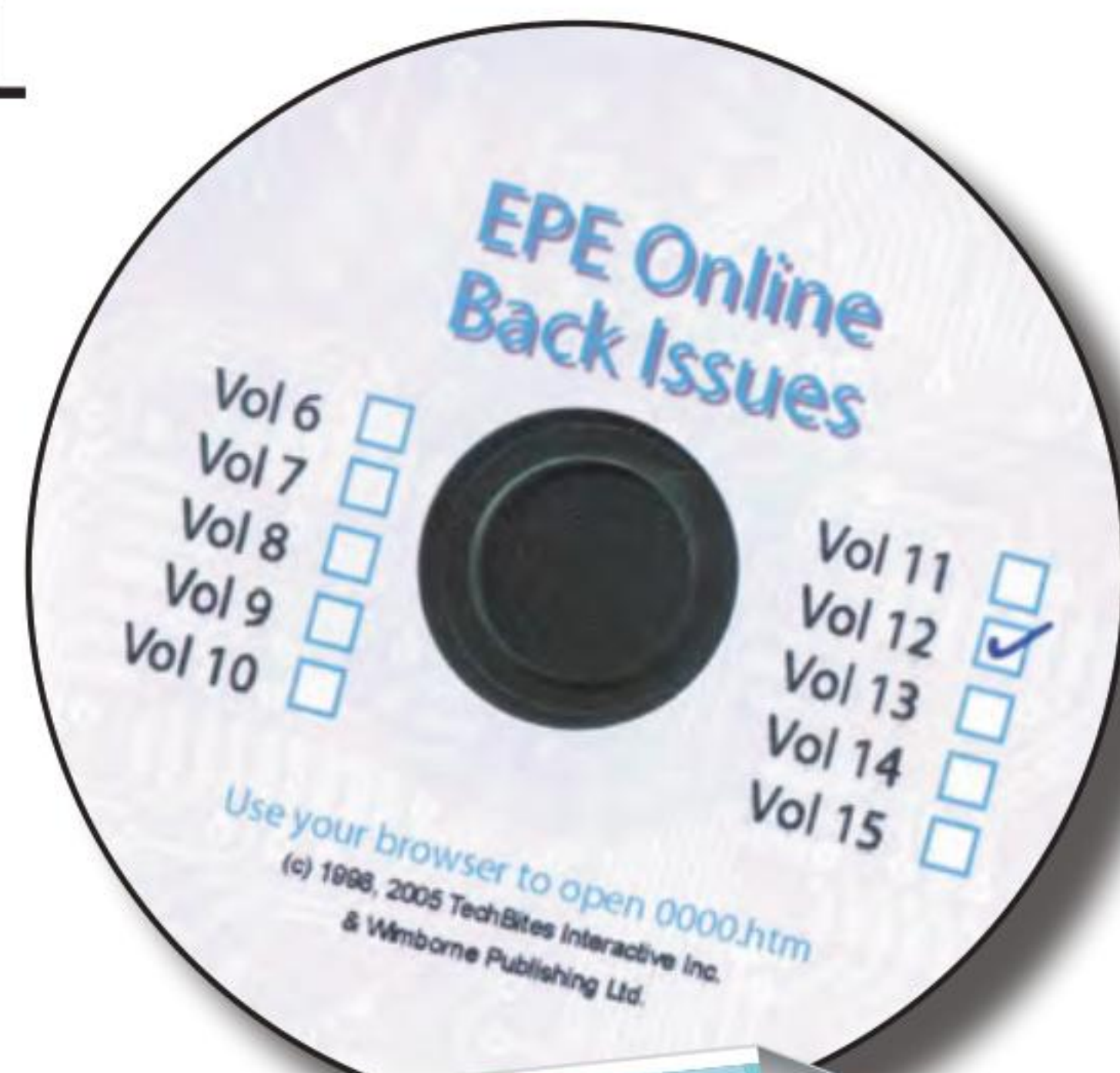
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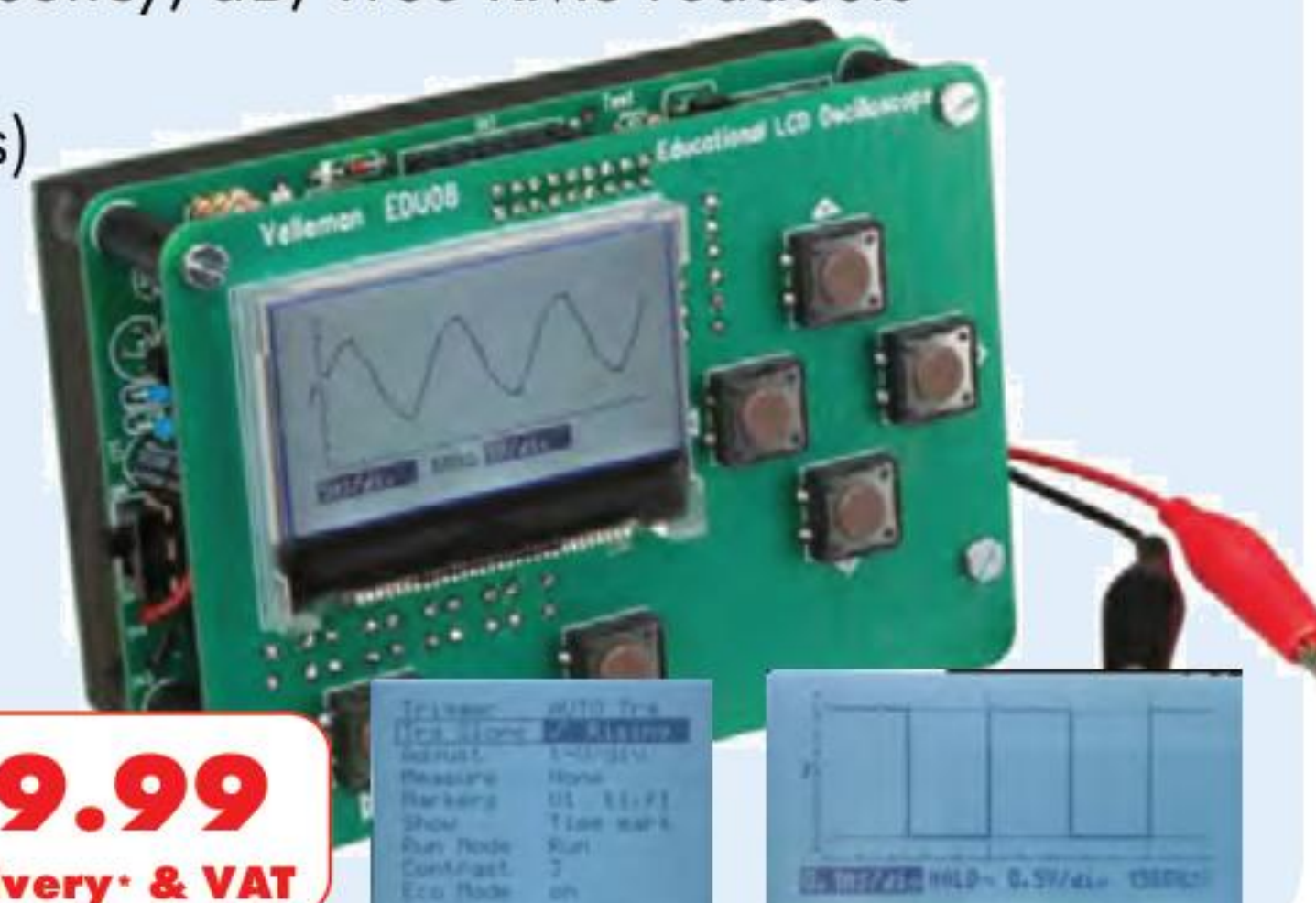
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Everyday Practical Electronics Advertisements
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Phone: 01202 880299 Fax: 01202 843233

Email: stewart.kearn@wimborne.co.uk

Editor:

MATT PULZER

Subscriptions:

MARILYN GOLDBERG

General Manager:

FAY KEARN

Graphic Design:

RYAN HAWKINS

Editorial/Admin:

01202 880299

Advertising and**Business Manager:**

STEWART KEARN

01202 880299

On-line Editor:

ALAN WINSTANLEY

Publisher:

MIKE KENWARD

READERS' TECHNICAL ENQUIRIES

Email: fay.kearn@wimborne.co.uk

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In memoriam, Jack (1878-2016)

138 is not a bad age to go. In fact, in the world of electronics it's an
extraordinarily long life. Jack, or 'jack plug' as I should really call him,
has finally been given the heave-ho by Apple, which in the most recent
incarnation of their iPhone have removed the formerly ubiquitous jack
socket and replaced it with their own Lightning connection system for
headphones, plus – of course – wireless options for their latest Bluetooth
in-ear 'AirPods'.

Jack (as well as his many siblings, including miniature, sub-miniature and
stereo) dates all the way back to 1878 when the original ¼-inch version
was developed for use in manual telephone exchanges. In fact, reports of
his death are undoubtedly exaggerated. There must be literally billions of
perfectly good jack-connected headphones, musical instruments and other
pieces of audio equipment that will last and last, and even a company as
famously stubborn as Apple recognised this by including a jack adapter
with the new iPhone.

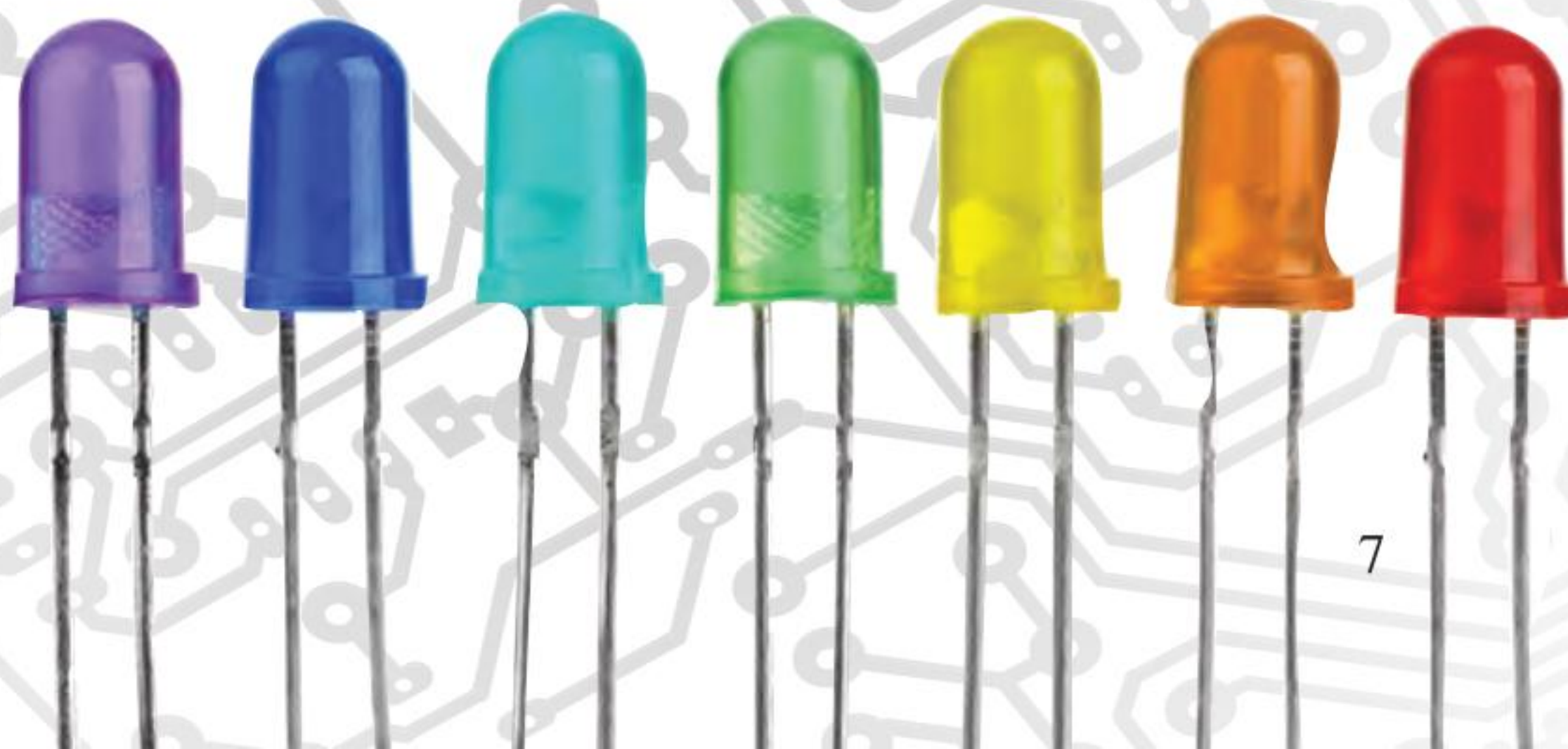
So why did the jack plug last so long? Often, something lasts simply
because it was the first to appear, and became a *de facto* standard that
reinforced its market dominance. From an engineering point of view the
jack plug is not an ideal design, but you don't need to be the best to win
market share, as Sony's Betamax sellers discovered, you just need to be
cheaper or easy to use. However clever Apple's new connector may be, it
lacks the near-universal market penetration and cheapness of the jack plug,
so it will be interesting to see if this really is the end of the Jack, or just a
temporary blip in his popularity.

Waving the flag for UK wall sockets!

It's not often you get the chance to hum *Rule, Britannia!* in the world of
mains connector technology, but Massachusetts-based tech writer John
Brownlee is such a huge fan of our trusty 13A plug and socket combo that
he has written a paean to celebrate the design: <http://tinyurl.com/gpref9y>

Now, before I get inundated with furious emails from patriotic readers
outside the UK, who would quite rightly like to point out that their country
also boasts wonderful wall sockets, I would like to make it clear that while
I certainly appreciate the wonderful safety of BS 1361 (see www.bs1361.org.uk) my aesthetic favourite is not the UK design, but the Danish one.
The Danes, with their typical, understated design flair manage to elicit a
smile each time I look at one of their sockets – just visit: <http://tinyurl.com/zuhhqfq>.

Min



NEWS

A roundup of the latest Everyday News
from the world of
electronics



New remote control technology – report by **Barry Fox**

When the late Akio Morita, founder of Sony, was asked what he thought was the most important innovation in consumer electronics, he answered laconically ‘remote control’.

Gesture, voice and beyond...

Early remotes used ultrasound, and equipment could be falsely switched by high-pitched squeals, for instance from milk cart brakes. Then came infra-red, which still serves well. The modern trend is towards visible gesture control, and voice control. Amazon and Google have recently patented interesting new ideas in this field.

Cancelling noise cancellation

Naming two inventors (Benjamin Scott and Mark Rafn) from Cambridge in the UK, Amazon Technologies of Reno, Nevada, recently won a US patent (9,398,367) for ‘Suspending noise cancellation using keyword spotting’. The patent tackles a practical problem with noise-cancelling headphones; as well as killing background noise in the room, the headphones can stop the wearer hearing what someone in the room is trying to say to them.

So Amazon plans to build intelligent circuitry into headphones which can be trained to recognise specific key words or phrases, such ‘Hey’ or ‘Hey Ben’. When the headphones ‘hear’ this key they suspend or modify the noise-cancellation. The wearer can then hear what is being said.

The circuitry does not have to offer fully-fledged speech recognition, just the ability to spot a few simple sounds. However, it can be trained to recognise a particular voice so the headphones do not falsely react to an actor on TV saying, ‘Hey’.

Google moves to radar

Meanwhile, Google wants to use local radar transmitters and sensors instead of a video camera to control equipment such as a TV, PVR, refrigerator, computer or central heating system, with no need for line of sight between the user and the sensor.

Details of the idea are now being revealed in a string of lengthy applications that were filed at the US Patent Office by Google Inc of Mountain View, California through 2014 and are now being published for open access (20160098089, 20160055201, 20160054792, 20160041618, 20160041617 and 20150346820). All the applications name Ivan Poupyrev, of Sunnyvale, as one of the inventors.

Google’s patents suggest a wide scope of uses, such as searching on a mobile by pointing across the street at a coffee shop, or car or tree, and asking for information on it. Radar can also be used to monitor health conditions biometrically, for instance during exercise; and it can distinguish between different people in the same room, for multi-player games.

Network integration of radar

The GHz frequencies used for the radar fields, and the power at which they operate, are chosen to suit the devices and their working location. The radar detectors connect to a conventional network, wired or wireless, Wi-Fi or cellular, which then controls the devices in a conventional manner. The high frequency radar field can also be used to carry data between devices.

Although Google’s concept is broad, and the patents are rather thin on precise details of construction and design, the fact that industry giant Google is behind the filings

makes it unwise to write them off as fanciful ‘armchair patents’.

Better human-machine interfaces

Although more and more people are now using wearable electronics, the fiddly user interfaces are often very hard to use, says Google. Life will be much easier if wearables can be controlled by the wearer’s gestures. The gestures can be the same as those used for standard deaf-aid sign languages. The radar field may be generated by fixed transmitters in the home or office or store, by a smartphone, or by wearable devices such as a watch.

Google gives many examples of radar control. If someone enters ‘Best Italian restaurant?’ as a search term on a mobile it will give much more useful results if the user can assist by sweeping the mobile over the immediate surroundings. Getting information on an unknown object – such as a building – will be easier if the mobile knows what the user is looking at.

Instead of struggling with tiny buttons or screen icons on a wearable, the wearer can use one hand to tap on top of the other hand, with the tapping pattern detected by a local radar field generated by the wearable, or by a glove or by a transmitter embedded in a jacket sleeve.

At the same time, the radar field is monitoring the condition of the wearer’s skin, to measure temperature, detect excessive perspiration and log heart rate. The results can alter an air conditioner setting, turn on a fan or trigger a health alarm.

In a home or office, fixed transmitters – perhaps embedded in the walls – bathe the room in a radar field that detects any pre-programmed gesture made by the occupants’ arms or hands.

New remote control technology continued

The over-riding advantage of using radar detectors, with direct and reflected fields, instead of line-of-sight cameras, is that gesture commands are not blocked by furniture, or walls. By combining biometric sensing with gesture recognition, multiple appliances can be controlled by

multiple people, from almost anywhere in the vicinity.

This technology means there is no longer any need for people to sit awkwardly where they can touch a screen, says Google. Everything can be controlled by waving hands, arms or even legs and feet.

IBM breakthrough imitates neurons



The array of tiny squares are contact pads that are used to access the nanometer-scale phase-change cells (not visible). The sharp probes touch the contact pads to change the phase configuration stored in the cells in response to the neuronal input.

IBM researchers have created randomly spiking neurons using phase-change materials to store and process data. This demonstration marks a significant step forward in the development of energy-efficient, ultra-dense integrated neuromorphic technologies for applications in cognitive computing.

Inspired by the way the biological brain functions, scientists have theorised for decades that it should be possible to imitate the versatile computational capabilities of large populations of neurons. However, doing so at densities and with a power budget that would be comparable to those seen in biology has been a significant challenge, until now.

‘We have been researching phase-change materials for memory applications for over a decade,’ said IBM Fellow Evangelos Eleftheriou. ‘We have discovered new memory techniques, including projected memory, stored 3 bits per cell in phase-change memory, which can perform various computational primitives such as data-correlation detection and unsupervised learning at high speeds using very little energy.’

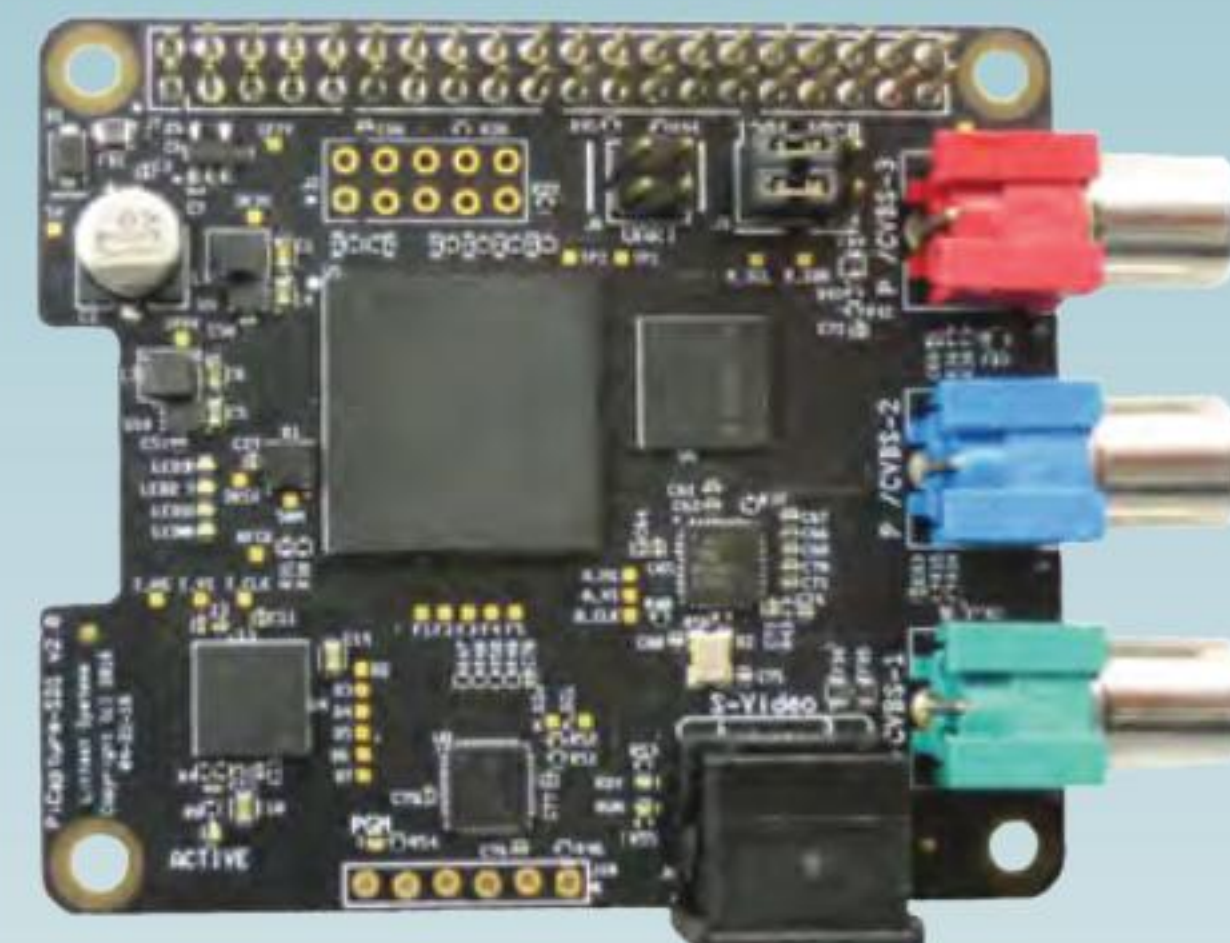
The artificial neurons designed by IBM scientists in Zurich consist of phase-change materials, including germanium antimony telluride, which exhibit two stable states, an amorphous one (without a clearly defined structure) and a crystalline one (with structure). These materials are the basis of re-writable Blu-ray discs. However, the artificial neurons do not store digital information; they are analogue, just like the synapses and neurons in our biological brain.

The team applied electrical pulses to the artificial neurons, which resulted in the progressive crystallisation of the phase-change material, ultimately causing the neuron to fire. In neuroscience, this function is known as the integrate-and-fire property of biological neurons. This is the foundation for event-based computation and, in principle, is similar to how our brain triggers a response when we touch something hot.

Exploiting this integrate-and-fire property, even a single neuron can be used to detect patterns and discover correlations in real-time streams of event-based data. For example, in the Internet of Things, sensors can collect and analyse volumes of weather data collected at the edge for faster forecasts. The artificial neurons could be used to detect patterns in financial transactions to find discrepancies or use data from social media to discover new cultural trends in real time. Large populations of these high-speed, low-energy nano-scale neurons could also be used in neuromorphic coprocessors with co-located memory and processing units.

The IBM researchers have organised hundreds of artificial neurons into populations and used them to represent fast and complex signals. Moreover, the artificial neurons have been shown to sustain billions of switching cycles, which would correspond to multiple years of operation at an update frequency of 100Hz. The energy required for each neuron update was less than 5pJ (five pico-joules) and the average power less than 120µW.

Video capture on Raspberry Pi



Lintest Systems has launched a pair of interesting products called PiCapture – a video capture solution that enables all of the video processing and software capability of the Raspberry Pi by emulating the Raspberry Pi camera. Powered by a custom-designed, high-performance video processor, the two versions (standard definition and high definition) allow all of the Raspberry Pi’s CPU power to be used for applications and not consumed by limited-function, outboard USB devices. Packaged in a Pi-compatible form factor with a 40 pin GPIO feed-through header means compact installations on a Raspberry Pi.

Since PiCapture fully emulates the Raspberry Pi camera module, all software (eg, Raspidvid or PiCamera) is fully compatible.

There are two PiCapture’s variants, SD1 is for standard definition interlaced video (NTSC/PAL) from composite, S-Video, and YPbPr component. PiCapture HD2 is for high-definition progressive video from digital (HDMI/DVI), analogue (YPbPr component), and computer (RGB) sources at 480p, 720p, and 1080p resolutions.

New Hammond enclosures

The 1590 die-cast enclosures family from Hammond Electronics consists of 41 different sizes in standard rectangular and ‘STOMP’ box style. STOMP boxes, also known as guitar effect pedals, are the housings for foot-operated equipment used by electric guitarists to produce preset effects. Two new sizes, the 1590 BX2, 254 × 70 × 35mm, and 1590 BX, 254 × 70 × 51mm, have been added to the range to allow multiple pedals to be mounted in a single enclosure.

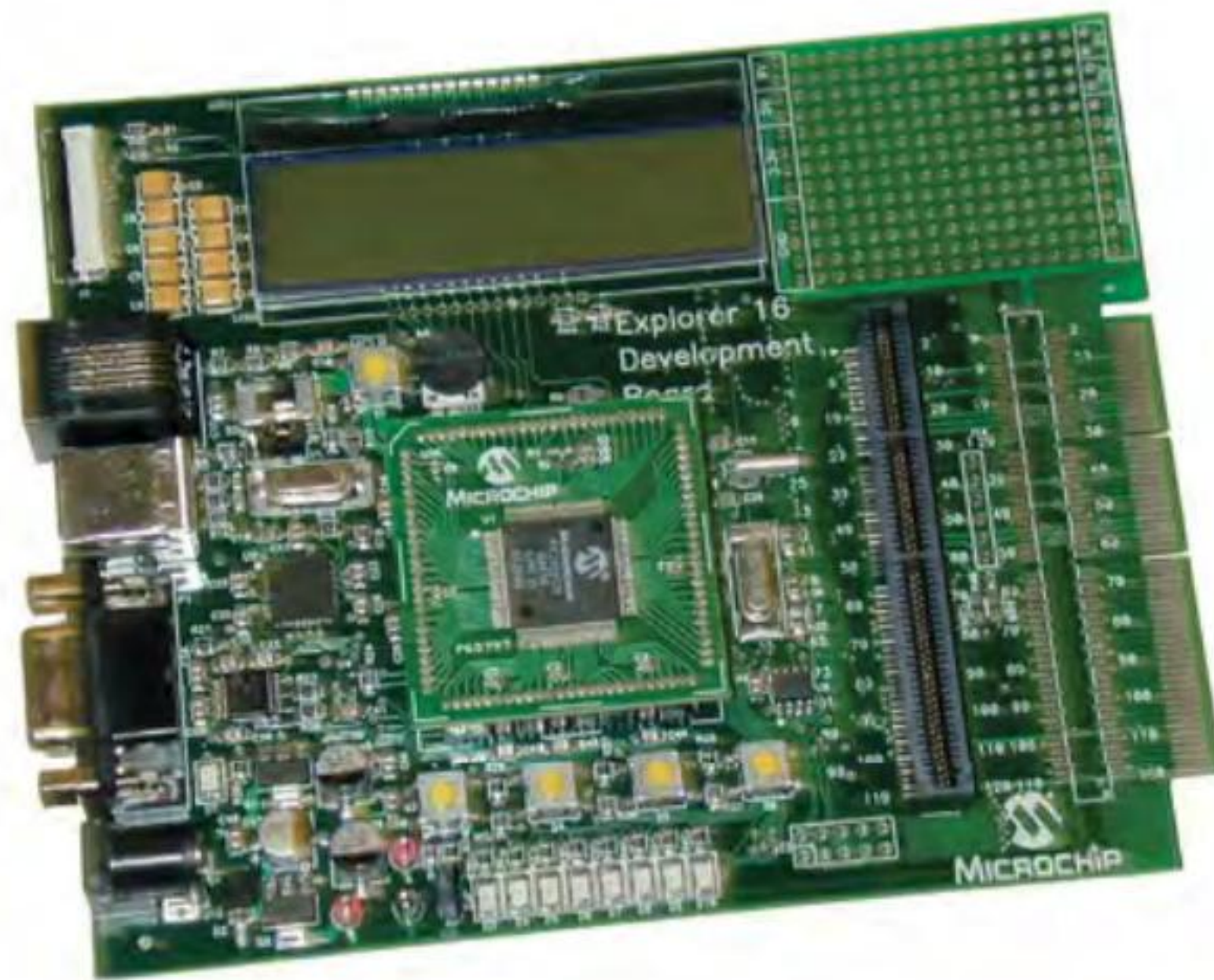
Free pocket reference from TI

Why not treat yourself to a free and very handy pocket guide from Texas Instruments – all you have to do is go to: <https://www.ti.com/seclit/sl/slyw038b/slyw038b.pdf> to download this excellent ebook.



Development Tool of the Month!

Explorer 16 Development Board with 100-pin PIM



Part Number
DM240001

Overview:

The Explorer 16 Development Board is a low-cost modular development system for Microchip's 16-bit and 32-bit microcontrollers. It supports devices from the PIC24, dsPIC® DSCs and PIC32 families. A variety of families are supported with processor Plug-In Modules (PIMs) for easy device swapping. The board includes a PICtail™ Plus daughter card connector for expansion boards including USB, CAN, Ethernet, wireless, graphics and many more. Coupled with the MPLAB® ICD 3 In Circuit Debugger or MPLAB REAL ICE, real-time emulation and debug facilities speed evaluation and prototyping of application circuitry.

Key Features:

- ▶ Includes processor PIMs for both PIC24 and dsPIC DSC families
- ▶ Alpha-numeric 16 x 2 LCD display
- ▶ Interfaces to MPLAB ICD 3, MPLAB REAL ICE and RS-232
- ▶ Includes Microchip's TC1047A high accuracy, analog output temperature sensor
- ▶ Expansion connector to access full devices pin-out and bread board prototyping area
- ▶ PICtail Plus connector for expansion boards

Order Your Explorer 16 Development Board Today at:
www.microchipdirect.com



When brilliant ideas miss the mark

TechnoTalk

Mark Nelson

What's not to like about LED street lamps? They're far more efficient than the lamps they replace, contain no toxic chemicals and reduce overall carbon emissions. But a lot of people feel unsafe where they have been installed, finding them too dim and eerily 'unnatural', while scientists and medical experts are now reporting serious health and environmental effects. Meanwhile many local authorities continue with mass conversion programmes, replacing their sodium lamps with LEDs. Have they got it all wrong?

IN A WORD, 'YESBUTNOBUTYES'...

or is that five? No matter. But first, let's examine the arguments in favour of converting to LED street lamps. Top of the list is energy-efficiency: the maximum 'net efficacy' of LED illumination is 90 per cent against 68 per cent for high-pressure sodium, the technology used in modern 'orange' street lamps. Fewer lighting columns are needed – just three LED lampposts can replace five or six sodium equivalents. Less electricity is consumed, leading directly to major financial benefits for financially squeezed local authorities; less electricity generation (so fewer power stations needed) and reduced carbon emissions. LEDs contain no toxic chemicals such as mercury, which is found in traditional high-pressure sodium and mercury vapour lamps. Finally, because LEDs are based on solid-state technology, they can be controlled and programmed more readily, which makes them one of the most versatile light sources available.

More reasons to be cheerful

A report published by the IEA (International Energy Agency) stated that doubling lighting efficiency globally would have a climate impact equivalent to eliminating half the emissions of all electricity and heat production in the EU. In the United States alone, cutting the energy used by lighting by 40 per cent would save US\$53 billion in annual energy costs, reducing energy demand equivalent to 198 mid-size power stations. And by using better-designed new light fittings, all the light could be focussed downwards onto our roads, streets and pavements, reducing the pallid orange glow that pollutes the night sky over built-up areas.

All this should please council tax payers, yet many complain that the new, cheaper LED lights are simply not bright enough. Signs are hard to read. Motorists find it even more difficult to spot the cyclists who don't use lights on their bikes. Road users complain of glare directly under the lamps and claim that the 'unnatural' blue-white light destroys their night vision. On

the other hand, they say that high-pressure sodium lighting is far more effective for night driving and even the old monochromatic low-pressure sodium lights are superior to LEDs.

All in the mind?

Not at all, the American Medical Association (AMA) – the largest association of physicians and medical students in the United States – vindicates these 'gut feelings', saying that although strong arguments exist for replacing the lighting systems on roadways with LEDs, conversion using improper LED technology can have adverse consequences. At their annual meeting in June they issued guidance for minimising potentially harmful human and environmental effects. Specifically, they confirm that high-intensity LED lighting emits a large amount of blue light that appears white to the naked eye and creates worse night-time glare than conventional lighting. Discomfort and disability from intense, blue-rich LED lighting can decrease visual acuity and safety, leading to anxiety and creating a road hazard.

That's not all. Blue-rich LED street lights operate at a wavelength that most adversely suppresses melatonin during night. It is estimated that white LED lamps have five times greater impact on circadian sleep rhythms (ie, the 'body clock') than conventional street lamps. Recent large surveys found that brighter residential night-time lighting is associated with reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime functioning and obesity. Finally, they assert the detrimental effects of high-intensity LED lighting are not limited to humans. Excessive outdoor lighting disrupts many species that need a dark environment and can disorient some birds, insects, turtles and fish species.

In Canada, Prof Johanne Roby agrees, arguing: 'Our body is not able to distinguish daytime from night time any more – and can't rest. It's just getting worse and worse, and it's starting to be scary. All around us, we're being exposed to more

artificial light than ever, and the increasing efficiency of that light is creating harmful consequences.' According to Robert Dick, chair of The Royal Astronomical Society of Canada's Light-Pollution Abatement Committee, light pollution is changing our environment into one for which we have not evolved.

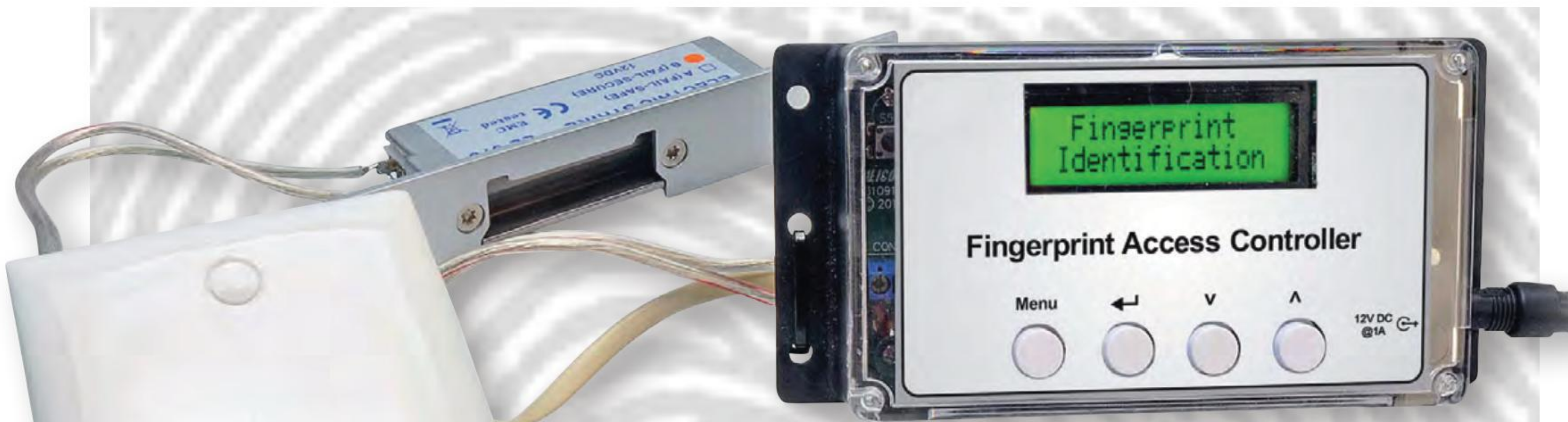
What's the solution?

Recognising the detrimental effects of poorly-designed, high-intensity LED lighting, the AMA is encouraging communities to minimise and control blue-rich environmental lighting by using the lowest emission of blue light possible to reduce glare. The Association also recommends that all LED lighting should be properly shielded to minimise glare and detrimental human health and environmental effects. Consideration should be given to utilise the ability of LED lighting to be dimmed for off-peak time periods.

Considered opinion now sees the best compromise is exploiting the advantages of LEDs and opting for devices having minimal blue light content. Amber LEDs would be ideal, with the added advantage that amber light has the least impact on living things at night. Their efficiency is not as high as LEDs that produce blue-white light, however. The solution is the more efficient type of PC (standing for phosphor-converted) amber LED, which is a standard white LED coated with an outer phosphor layer that removes the blue emission almost entirely.

Way to go

It may be some time before all local authorities are sufficiently enlightened to install amber street lighting, but we can hope that they see the light before long. One place that has already done this is the village of Santa Pau in the Garrotxa region of Spain – see: <http://tinyurl.com/zf8xr34>. A prime reason for opting for amber lighting is the proximity of the Garrotxa Natural Park, which is a protected area for dark skies. Annual energy savings of 21,000kW-hr are another welcome benefit for the village council.



By JOHN CLARKE

Open doors with this Fingerprint Access Controller

Uses a fingerprint scanner and an electric door strike

Do you hate carrying keys? So do we! Would you like to open your front door, security gate or your garage door with your finger? Now you can! This project comprises a fingerprint scanner (FPS), a 2-row LCD and an electric door strike, all controlled by a PIC16F88 microcontroller.

SOME LAPTOP PCs and smart-phones have a fingerprint scanner to enable you to access them and now you can build a project which works along similar lines. It can store and recognise up to 20 fingerprints and can give access to your home or workplace at any time, day or night. There's no need to fiddle around with keys – all you need is a finger!

The fingerprint scanner (FPS) we have used is the GT-511C1R, made by ADH-Tech in Taiwan. It's available from Cool Components in the UK for around £20 – not cheap, but it's worth remembering that getting multiple

copies of door keys for several people can be expensive.

The GT-511C1R FPS comprises an optical sensor (specifically a CCD camera) with an opaque screen (14 × 12.5mm) which you cover with your finger, to scan it. The camera records the fingerprint image which is compared with those stored in a database. If your print is in the database, the micro will unlatch the door, via the electric door strike.

As can be imagined, there is a lot of processing required to compare one fingerprint with a database and the GT-511C1R uses an ARM Cortex-M3 32-bit

processor that's specifically designed for real-time data processing; ideal for processing the 240 × 216 pixel image of a fingerprint. It breaks the photographed image down into a 504-byte template that becomes a digital representation of the fingerprint.

The fingerprint image capture, digital template data and fingerprint identification take place in the FPS, but to make it work, it must be used with a computer or microcontroller. Connection to the FPS is via a JST-SH 4-way wired header plug, which provides DC power and serial lines to carry the commands and the data.

Main features

- Identifies up to 20 separate fingerprints
- LCD module guides operation
- Drives an electric door strike (latch) to open a door
- Enrolments and deletions easily accomplished
- Errors shown on LCD
- Adjustable door-strike activation period
- Adjustable scan resolution
- Additional security features

These commands are for switching on internal LEDs for backlighting the FPS screen, and for enrolling or validating a fingerprint against those stored in the database. The computer or microcontroller does not need to be high-powered; a simple 8-bit microcontroller will suffice.

The data-sheet for the FPS is available at: www.coolcomponents.co.uk/fingerprint-scanner-5v-ttl.html (in the resources tab). There is an evaluation executable file that can be run on a computer using a serial port (or USB-to-serial converter) to connect to the FPS. The demonstration file is available at: https://cdn.sparkfun.com/datasheets/Sensors/Biometric/GT-511C1R_SDK_20140312.zip

While the demonstration file shows what the FPS can do, it is not suitable for a practical fingerprint security access system that can release the door strike of a door lock. For that, we need a more dedicated circuit and custom software.

Our system combines the GT-511CR FPS with a 2-line LCD module. This module is used when enrolling fingerprints and when selecting the various options using four pushbutton switches. These components, along with a PCB containing the PIC16F88 microcontroller, are mounted in a bulkhead case measuring 120 × 70 × 30mm. The whole works is powered using a 12V 1A DC plugpack, and this provides the brief power pulses for the electric door strike as well.

Features and operation

Normally, the FPS would be mounted on a wall-plate just outside the locked door, while the control box is mounted on the other side of the door. The

electric door strike is a door latch and when it is powered, the latch becomes free so that the door can be pushed open.

In normal operation, the FPS flashes its blue back-lighting LEDs once a second and each time checks whether a finger is pressed on the screen. If so, the LEDs stay lit and the fingerprint is compared with those in the database. The door-strike will then be briefly pulsed to open the door, if the fingerprint is valid.

If the fingerprint is not matched in the database or there are no current enrolments or there is a fingerprint reading error, the LEDs will flash rapidly at four times a second, for 2.5 seconds. At the same time, the error will be displayed on the LCD screen.

Other errors are related to security breaches, as discussed later. These will cause the FPS blue LED back-lighting to stay off until the fault is acknowledged, using the Enter button on the control panel.

To make it work, you need to enrol one or more fingerprints so there is a database. Enrolment and other functions are done using the four push-button switches on the control panel. The four buttons are, from left to right: Menu, Enter, Down and Up.

Once powered up, the default home-screen on the LCD shows **Fingerprint Security Access**. Repeatedly pressing the Menu button lets you cycle through five menus, the first of which is for enrolling a new identity (ID). The ID numbers can be scrolled up or down using the buttons and only the unused ID numbers will be shown. Pressing the Enter button then starts the enrolment procedure, during which you will be instructed to place your finger on the FPS.

The next menu is for deleting an enrolled ID. Only enrolled IDs will be shown, by scrolling up or down. Pressing the Enter button deletes the selected ID.

The third Menu deletes all enrolled IDs; useful if you want to clear everything and start again. It is much faster than deleting enrolments one by one.

The fourth and fifth menus let you adjust the scan resolution and the door-strike energising period. The door-strike operating period is adjustable from 1s up to 255s. The Up and Down buttons are used to make the changes.

The scan resolution sets the resolution of the captured fingerprint during



The FPS (fingerprint scanner) can be mounted on a blank wall-plate adjacent to the locked door, while the control box is mounted inside the room.



Shown here slightly larger than actual size, the GT-511C1R FPS can enrol up to 20 fingerprints. The module measures just 37 × 17 × 9.5mm (L × W × D).

access. It does not change the enrolment resolution of the fingerprints; that's always at the highest resolution. A low resolution selection makes the database search faster compared to using the high resolution selection.

The next press of the Menu button takes the system back to the home screen. Alternatively, the system will automatically return to the home-screen after 25 seconds if a menu item is selected and no further buttons are pressed.

Note that the LCD module lights up when any switch is pressed. It also lights when the LCD screen changes to indicate the type of access (whether allowed, denied or security errors). The

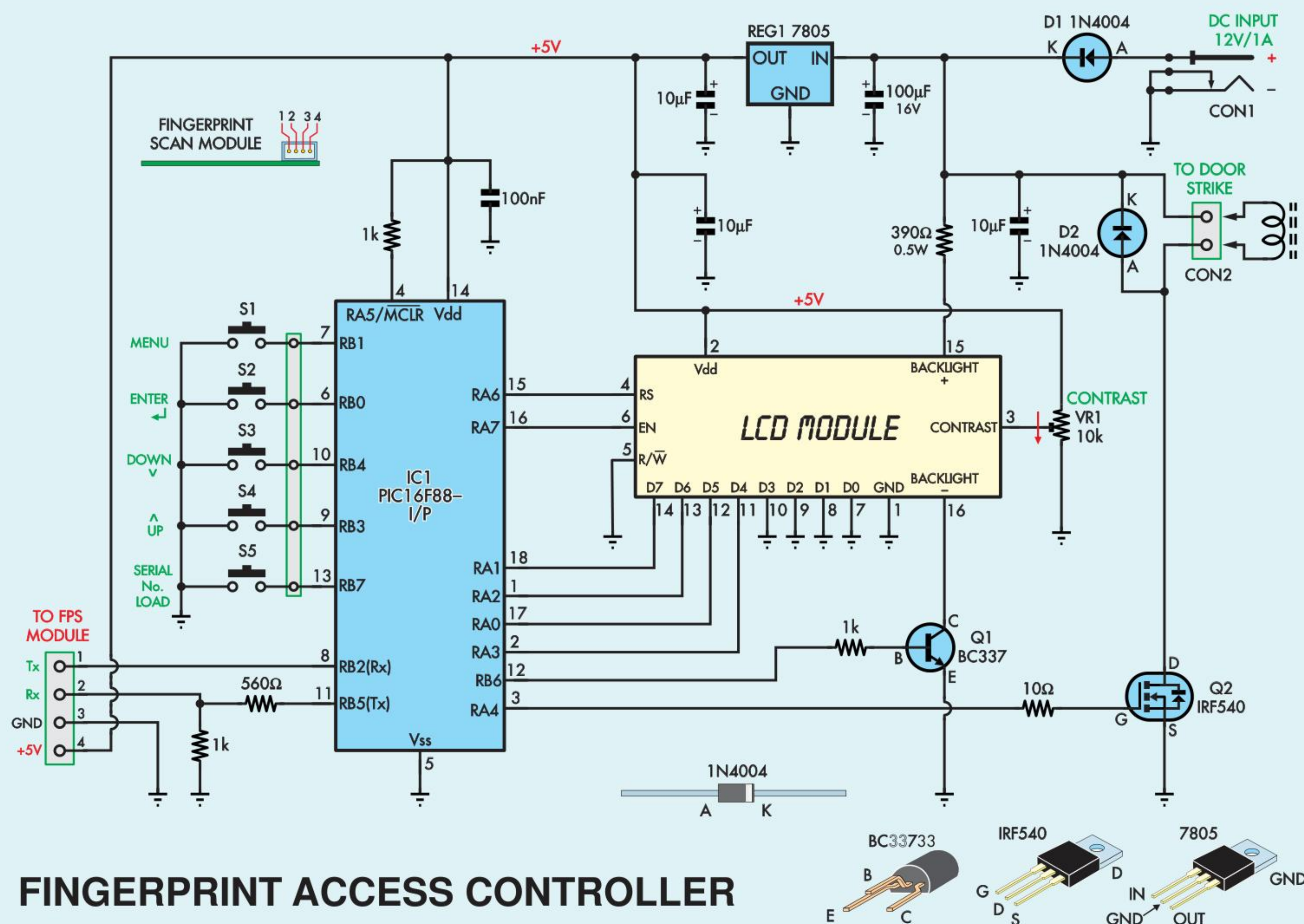


Fig.1: the circuit is based on a GT-511C1R FPS, PIC microcontroller IC1 and a 2-line $\times$ 16-character LCD module. IC1 sends and receives data to and from the FPS module via its serial port (pins 8 and 11), monitors pushbutton switches S1-S5 and drives the LCD. It also drives MOSFET Q2 to activate the electric door strike when a valid fingerprint is scanned by the FPS. Transistor Q1 is driven by IC1's RB6 output and controls the LCD's backlight.

backlight automatically turns off after 10 seconds, except for security breach errors, in which case the backlight will stay on.

Foiling security breaches

Since the FPS is likely to be located in an unsecured area, there is a risk of attempted security breaches. However, we have incorporated some features to make unauthorised tampering ineffective. First, if the FPS is swapped with another one, access will be denied because each FPS has its own unique serial number.

Second, if the original FPS is temporarily disconnected and connected to another *Fingerprint Access Controller* to set up a new enrolment (eg, with the intruder's fingerprint), this too will be foiled. Access will be denied even though the correct FPS is reconnected with the matching serial number. When the FPS is reconnected and a finger is subsequently detected

on the screen, the *Fingerprint Access Controller* will detect that the enrolments have changed. A tamper message will then be displayed on the LCD screen and all access will be denied.

Two other security measures are also incorporated to counteract any 'hot wiring' exchanges of the FPS. If the FPS is disconnected and reconnected while power is applied, the *Fingerprint Access Controller* will immediately halt operation, preventing any access.

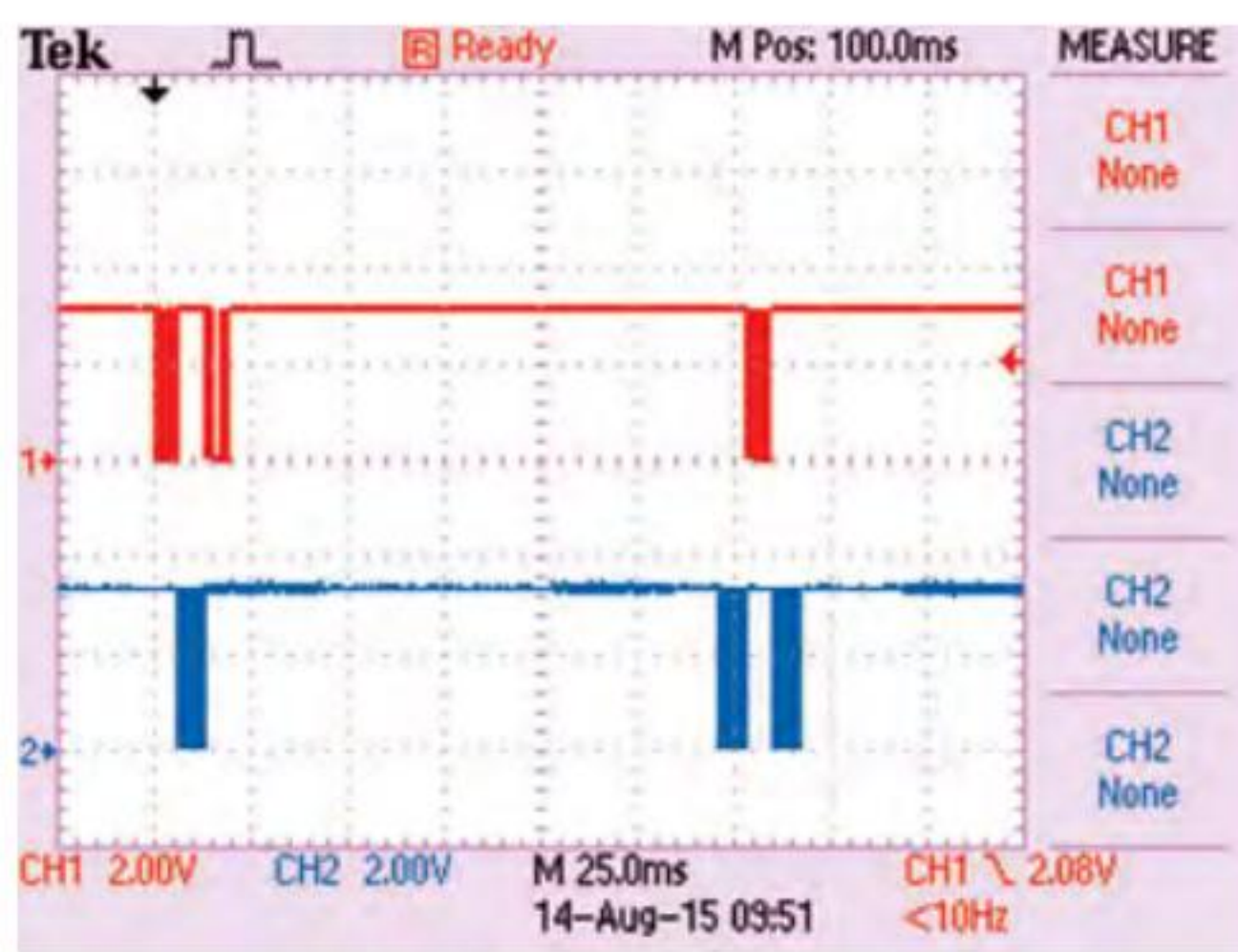
Similarly, if the FPS is quickly hot-swapped from one control unit to another using a switched lead, operation will halt. During this halt, the FPS will have its blue back-lighting off to indicate a fault. No indication will be issued on the LCD screen and the switches will not have any effect. The *Fingerprint Access Controller* will then need to be powered down and powered up again to restore operation.

Circuit description

Fig.1 shows the circuit for the *Fingerprint Access Controller*. It comprises the fingerprint scanner (FPS), a micro-controller (IC1) and a 2-line $\times$ 16-character LCD module. Each of these is complex in itself, but they make the rest of the circuit quite simple.

The LCD is driven by IC1 via its four most-significant data lines (D4-D7), while lines D0-D3 are tied to ground. When driving the LCD, data is sent in two 4-bit portions to make up the full 8-bit data. Driving the display in this way saves having to dedicate an extra four connections to IC1. The EN (Enable) and RS (register select) lines are driven via IC1's RA7 and RA6 ports to control the clocking and data flow to the LCD.

The LCD module's contrast control is trimpot VR1, which is adjusted to give the best screen contrast. Transistor Q1 controls the LCD module's back-lighting and its base is driven with a



Scope 1: the top trace of this scope grab shows the commands sent to the FPS during a scanning routine. First, the FPS backlight is switched on, then a check is made to detect if a finger is placed on the FPS screen. In this case, there is no finger present and so the backlighting is switched off. The lower trace shows the acknowledgement from the FPS.

PWM signal from IC1's RB6 output. The backlight LEDs are supplied via a 390Ω 0.5W resistor connected to the 12V supply (following diode D1).

The FPS module is driven by IC1's serial port. As shown, IC1's receive input (Rx) at pin 8 connects to the transmit (Tx) pin of the FPS module. Similarly, IC1's transmit (Tx) pin (pin 11) connects to the receive (Rx) pin of the FPS. A resistive divider reduces the 5V transmit signal from IC1 down to a nominal 0-3.3V to make it suitable for the FPS's Rx input.

The FPS uses an 8-bit data and one stop bit format and the default baud rate is 9600 baud. However, faster rates such as 19,200, 38,400, 57,600 and 115,200 baud can be selected by sending a command and baud rate parameter and IC1 actually does this, depending on its mode. Data sent to the FPS begins with four header bytes (55, AA, 01, 00) for the start bits and device ID, then a 4-byte parameter value followed by a 2-byte command value and 2-byte checksum. Acknowledgement from the FPS follows a similar format.

When reading the serial number, an extra 30 bytes of data is sent. This incorporates the 16-byte serial number, with the remainder being start bytes (this time it's 5A and A5), device ID, firmware version, size of captured image, serial number and a 2-byte checksum at the end. All data is sent and received with the least significant bytes first ('Little Endian', as the data sheet describes it).

The accompanying scope grabs illustrate the circuit operation. Scope1 shows the normal scanning routine

Specifications

Finger Print Scanner (FPS)

CPU: ARM Cortex-M3 core (32-bit)
Sensor area: 14 × 12.5mm
Image size: 240 × 216 pixels
Resolution: 420dpi
Maximum number of fingerprints stored: 20
Template size: 504 bytes
Communication: 9600 baud (default) to 115,200 baud, (eg, 19,200, 38,400, 57,600)
False acceptance rate: <0.001%
False rejection rate: < 0.1%
Identification time: minimum of 1.5s but usually longer depending on number of fingerprints stored
Operating Voltage: 3.3-6V
Current: 130mA with sensor LEDs on
Operating temperature range: -20°C to +60°C

Control Unit

Power supply: 12V DC @ 1A
FPS connection: JST-SH 4-way wired header plug lead (tested up to 1.2m long)
Current consumption: scanning, 150mA; FPS blue LEDs on, 200mA; door strike on 700mA
LCD backlight: turns on when a switch is pressed and during fingerprint detection; automatically turns off after ~25s
Fingerprint scanning: detect once per second with FPS LED flashing at 1Hz
Home screen: appears during scanning; automatically returns after 25s if no switches are pressed during this time
Door strike activation period: adjustable from 1-255s
Fingerprint scan resolution: selectable low or high
Enrolment control: add a new enrolment ID, delete an enrolment ID and delete all enrolments
Additional security: FPS unique serial number check; check for correct number of enrolments plus two more undisclosed security techniques

where the FPS backlight is switched on, then a check is made to detect if a finger is placed on the FPS screen. In this case, no finger is present and so the backlighting is switched off. The data sent to the FPS is the top trace and is shown in the above order, ie, backlight on, check for a pressed finger, then backlight off.

The acknowledgement from the FPS is shown in the lower trace and occurs immediately after the serial data is sent for backlighting on and off, but with a delay of around 125ms for the response while the FPS checks if a finger is present. The received serial data response length is about 7.5ms long in each case.

Scope2 shows the data sent to retrieve the serial number of the FPS. Note how much more data is returned, taking some 26.5ms compared to the

normal response of around 7.5ms.

Scope3 shows the complete code sent to switch the FPS backlight off, expanded out to 1ms per division.

Pushbuttons

IC1 also monitors pushbutton switches S1-S5 which are connected to inputs with internal pull-ups. These hold each input high (5V) unless a switch is pressed, which pulls the respective input low (0V).

The electric door-strike solenoid is driven via MOSFET Q2 and its gate is driven by IC1's RA4 output via a 10Ω resistor. One side of the door strike is connected to 0V when the MOSFET is switched on. The other terminal of the door strike connects to the 12V rail via reverse polarity protection diode D1. Diode D2 quenches the back-EMF pulse produced by

Constructional Project

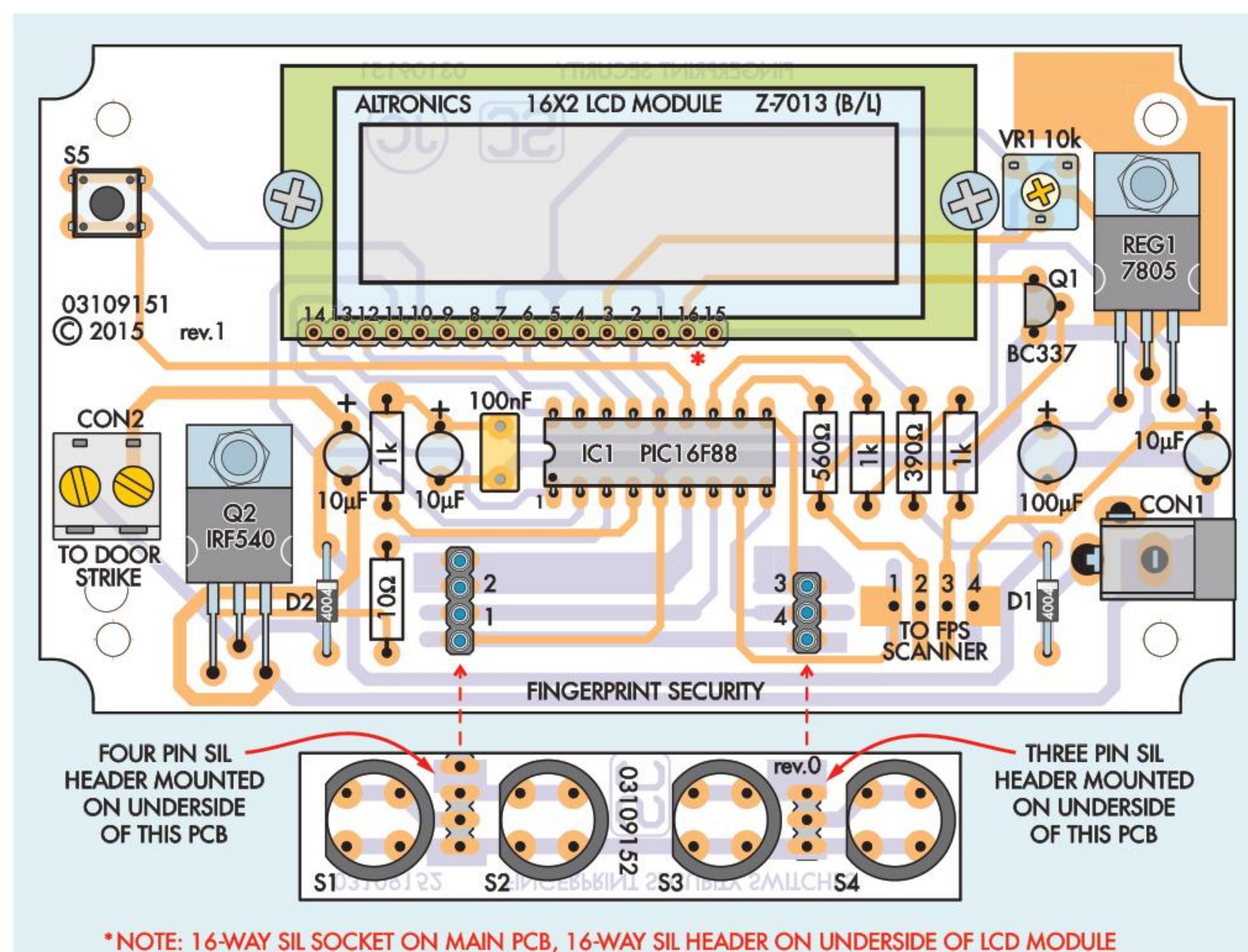
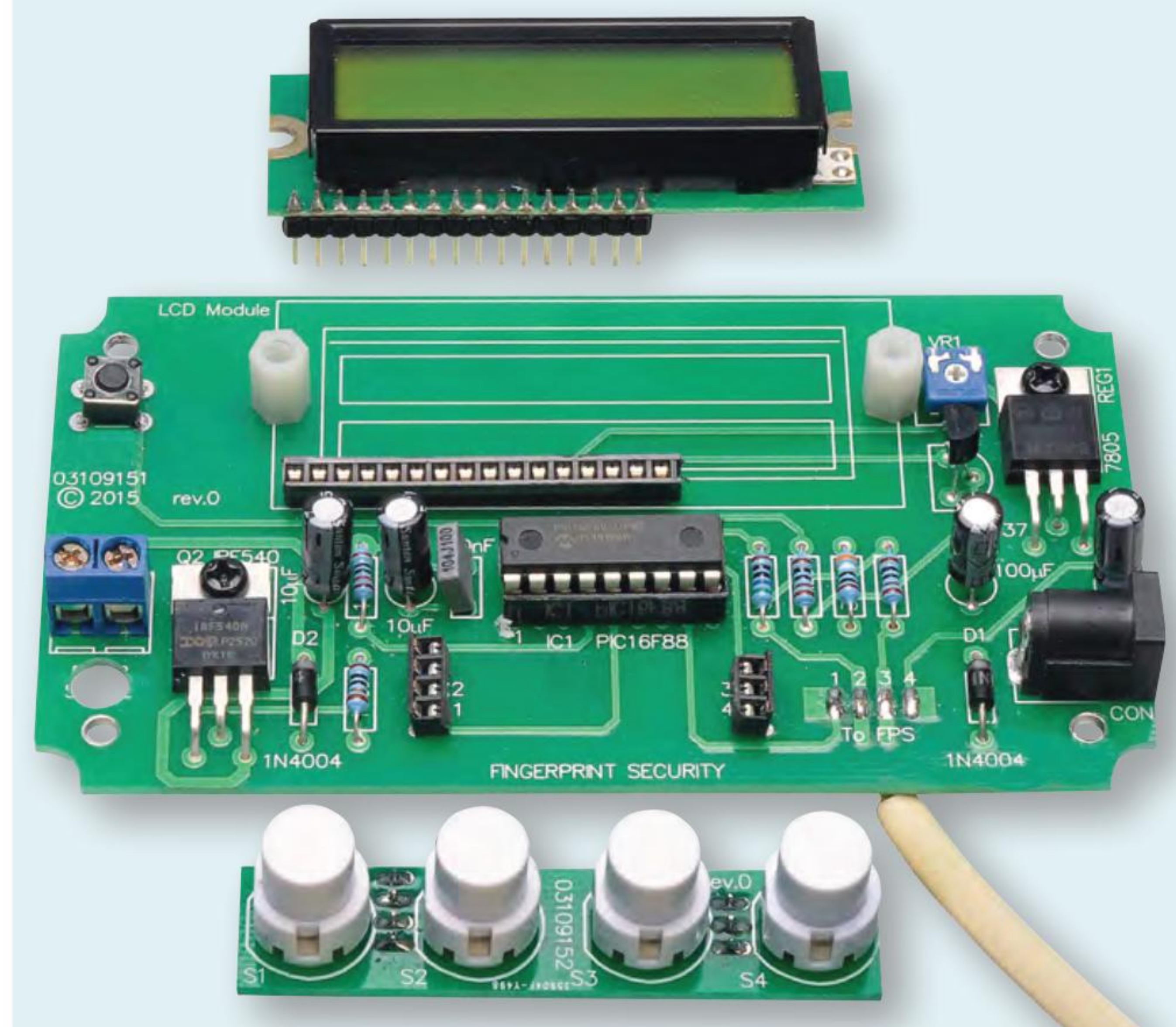


Fig.2: follow this parts layout diagram to build the two PCBs. Use a socket for microcontroller IC1 and make sure that all polarised parts (including switches S1-S4) are correctly oriented. The photo below shows the completed PCB assemblies, together with the LCD module.



the door-strike solenoid when it is switched off.

Garage door opener

The FPS does not have to be used with an electric door strike. For example, it could instead be used with a garage

door opener which is triggered by shorting two contacts; shorting the contacts operates the door, either to open or close it.

In that case, the source and drain of the MOSFET need to be brought out to a 2-pin connector and then connected

via a figure-8 cable to the switch contacts on the garage door opener.

Alternatively, a 12V relay could be wired to CON2 in place of the door strike to do the switching operation.

The supply for IC1, the LCD and the FPS is derived via REG1, a 5V 3-terminal regulator. A 100nF capacitor decouples the supply to IC1 close to its supply pins, while the supply for the LCD module is decoupled using a 10μF capacitor.

Power is applied from a 12V DC plugpack to REG1 via reverse-polarity protection diode D1. A 100 μ F capacitor decouples the supply to REG1, while its output includes a 10 μ F supply bypass capacitor.

Construction

All the parts for the *Fingerprint Access Controller* are installed on two PCBs: (1) a main board coded 03109151 ($114 \times 53.5\text{mm}$) which accommodates most of the parts, including the LCD module; and (2) a switch board coded 03108152 ($62 \times 14\text{mm}$) which accommodates the four pushbutton switches (plus two pin headers) and which plugs into the main PCB. Both of the PCBs are available from the *EPE PCB Service*. The completed assembly is housed in a $120 \times 70 \times 30\text{mm}$ bulk-head-style case with a transparent lid.

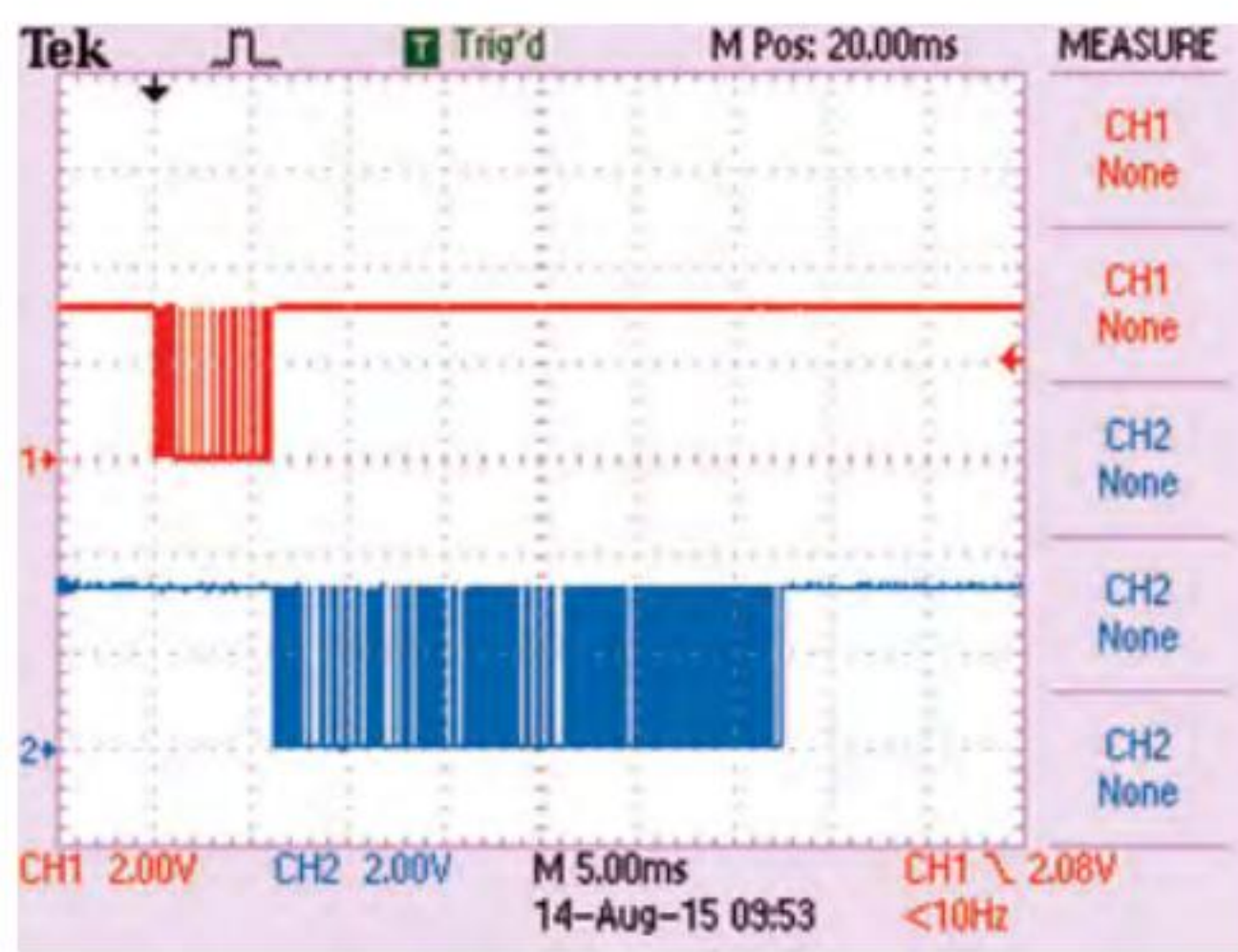
Fig.2 shows the parts layout on the two PCBs. The main board can be assembled first. Begin by fitting the resistors, taking care to install each one in its correct location. Table 1 shows the resistor colour codes but you should also use a digital multimeter to check each resistor before soldering it to the PCB.

Diodes D1 and D2 go in next (take care with their orientation), followed by an 18-pin DIL socket for IC1. The 4-way and 3-way SIL (single in-line) sockets, used to later mount the switch PCB, can then be installed.

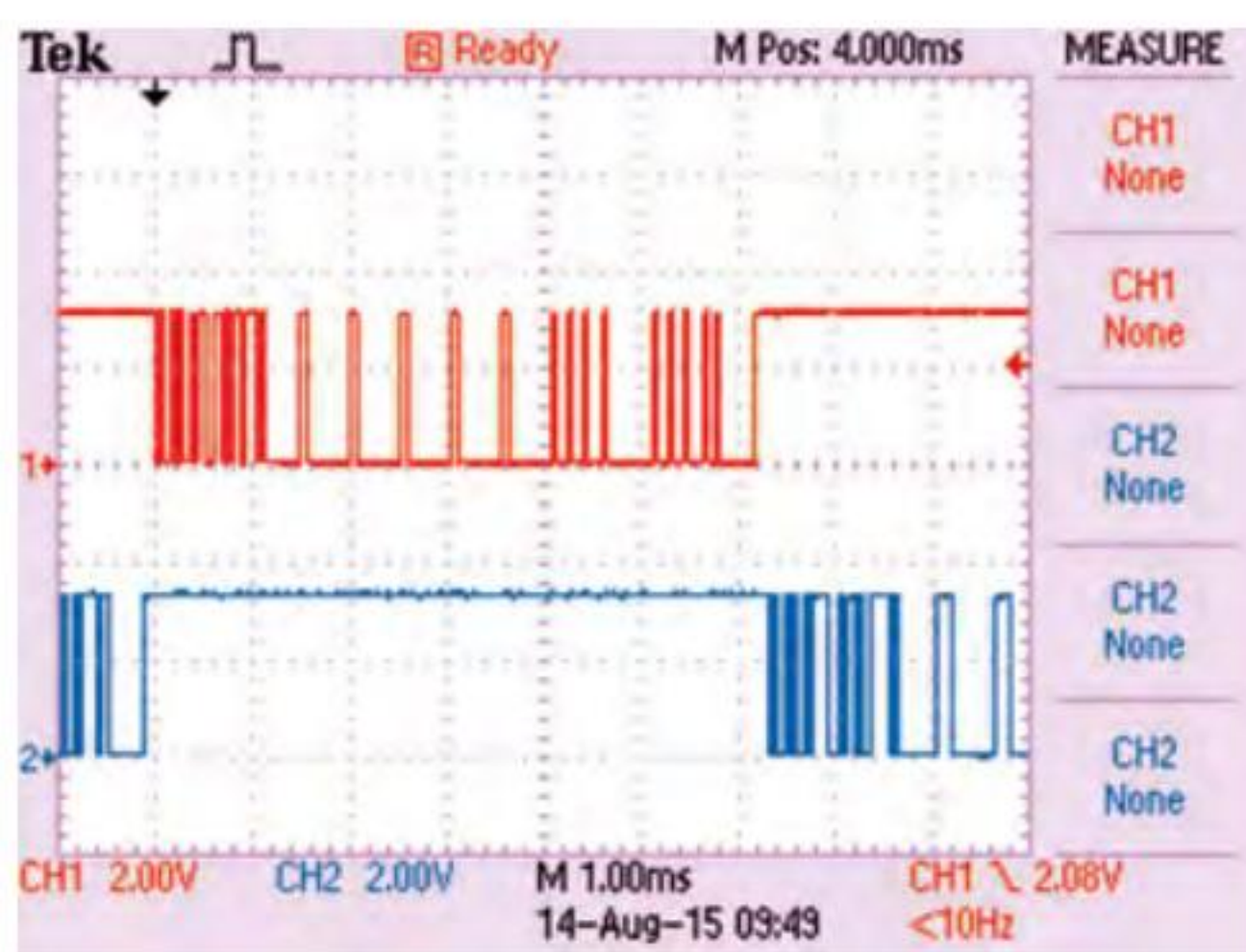
These socket strips are obtained by cutting down a DIL IC socket using a sharp knife or side-cutters. It's a good idea to smooth the cut edges with a file before installing the socket strips on the PCB. Similarly, the LCD module is mounted via a 16-pin SIL socket strip and this can also now be installed.

The capacitors are next on the list. Note that the electrolytic types must be oriented as shown.

Follow with REG1 and MOSFET Q2. These devices are mounted with their metal tabs flat against the PCB (ie, their leads must be bent down



Scope 2: this scope grab shows the data sent to retrieve the serial number of the FPS. Note how much data is returned, taking some 26.5ms compared to the normal response of around 7.5ms.



Scope 3: the complete code sent to switch the FPS's back-light off is shown here, expanded out to 1ms per division.

through 90° to pass through their respective holes). Secure each device to the PCB using an M3 × 6mm screw before soldering its leads. Don't solder the device leads first; if you do, the PCB tracks could crack as the tab screws are tightened down.

Be careful not to get Q2 and REG1 mixed up – they look much the same.

Transistor Q1 (BC337), trimpot VR1, the DC socket (CON1), the 2-way screw terminal block (CON2) and pushbutton switch S5 can then go in. Check that CON1 and CON2 sit flush against the PCB before soldering their terminals.

Switch PCB

Attention can now be turned to the switch PCB. The 3-way and 4-way

Parts List

- 1 double-sided PCB, available from the *EPE PCB Service*, coded 03109151, 114 × 53.5mm
- 1 double-sided PCB, *EPE PCB Service*, coded 03109152, 62 × 14mm
- 1 GT-511C1R fingerprint scanner (Littlebird Electronics SF-SEN-13007, Cool Components, UK)
- 1 JST-SH 4-way wired header plug, 200mm lead length (Littlebird Electronics PRT-10359)
- 1 12VDC 1A plugpack
- 1 bulkhead case, 120 × 70 × 30mm
- 1 blank wall-plate (to mount fingerprint scanner)
- 1 12V electric door strike (fail-secure)
- 1 16 × 2 LCD module with back-lighting
- 4 click-action pushbutton switches, PCB-mount, white (S1-S4)
- 1 SPST PCB-mount tactile switch (S5)
- 1 18-pin IC socket
- 1 40-pin IC socket cut into 16-way, 4-way / 3-way SIL header strips
- 1 23-way SIL header strip cut to 16, 4 and 3-way lengths
- 1 PCB-mount DC socket (CON1)
- 1 2-way screw terminal block, 5.08mm pin spacing (CON2)
- 2 M3 × 6.3mm tapped spacers
- 6 M3 × 6mm screws
- 2 M3 nuts
- 4 No.4 self-tapping screws

Semiconductors

- 1 PIC16F88-I/P microcontroller programmed with 0310915A. hex (IC1)

- 1 7805 5V 3-terminal regulator (REG1)
- 2 1N4004 1A diodes (D1,D2)
- 1 BC337 NPN transistor (Q1)
- 1 IRF540 N-channel MOSFET (Q2)

Capacitors

- 1 100μF 16V PC electrolytic
- 3 10μF 16V PC electrolytic
- 1 100nF MKT polyester

Resistors (0.25W, 1%)

- 3 1kΩ
- 1 560Ω
- 1 390Ω 0.5W
- 1 10Ω
- 1 10kΩ miniature trimpot, horizontal mount (VR1) (code 103)

Miscellaneous

- 1 1m length of 4-way rainbow or telephone cable (length to suit installation)
- 1 short length of 2mm-diameter heatshrink tubing
- 1 length of figure-8 wire to connect door strike
- 1 12V bezel indicator lamp (LED or filament type) (optional to show door-strike operation)

Where to buy a kit

A complete kit of parts for the *Fingerprint Access Controller* is available from Altronics for £75, Cat. K 9350. This kit will include the GT-511C1R module and a punched wall plate but not the door strike.

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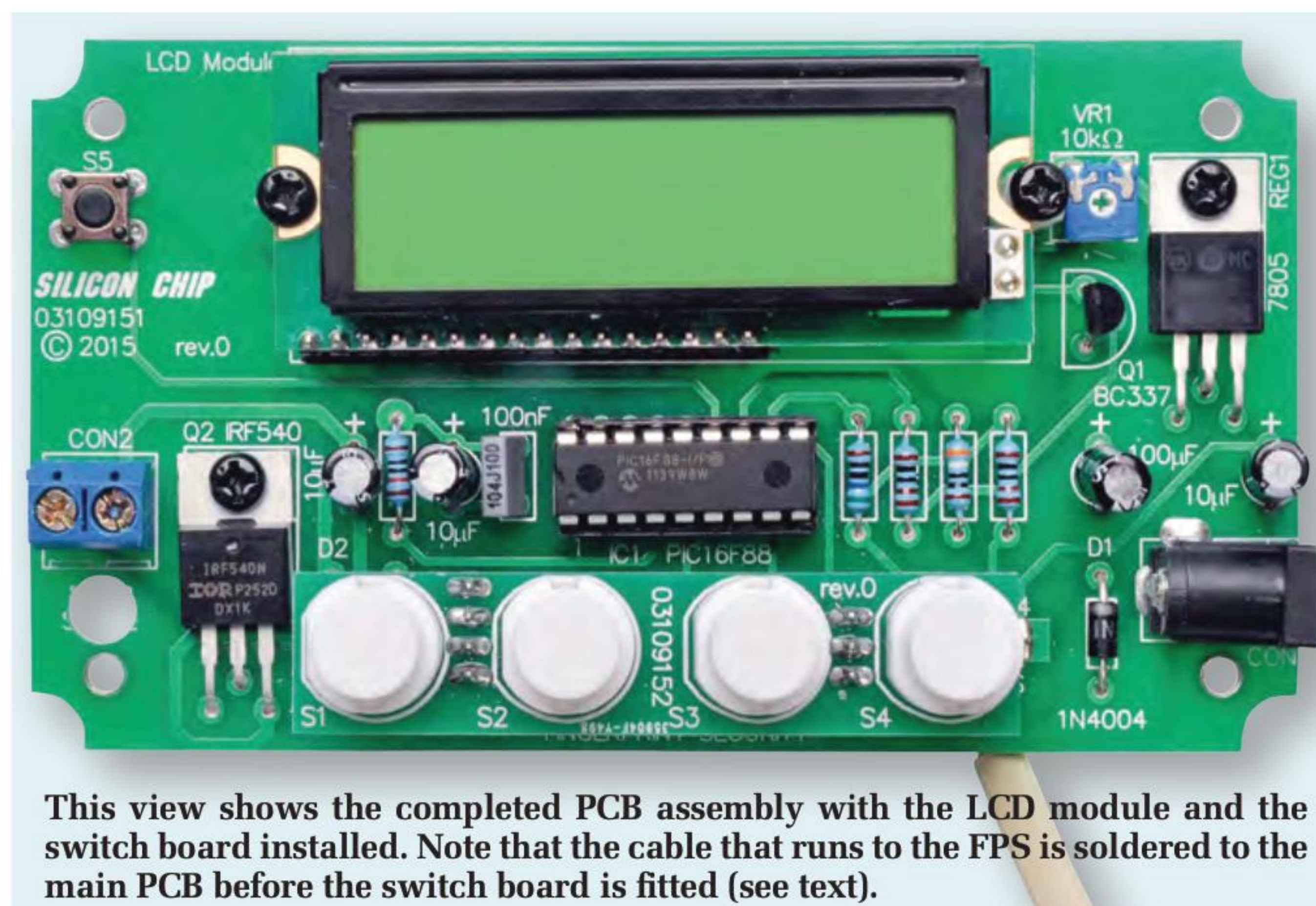
pin headers go in first. These are installed on the underside of the board and must be fitted with their shorter pin lengths going into the PCB holes. The header pins are then soldered on the top (switch side) of the PCB.

Once the headers are in place, the four pushbutton switches (S1-S4) can then be fitted. Install them with the flat side of each switch oriented as shown and make sure that they sit flush against the PCB before soldering their pins.

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
□	3	1kΩ	brown black red brown	brown black black brown brown
□	1	560Ω	green blue brown brown	green blue black black brown
□	1	390Ω	orange white brown brown	orange white black black brown
□	1	10Ω	brown black black brown	brown black black gold brown

Constructional Project



This view shows the completed PCB assembly with the LCD module and the switch board installed. Note that the cable that runs to the FPS is soldered to the main PCB before the switch board is fitted (see text).

The assembled switch PCB can then be plugged into the main PCB, but note that there is a right way and wrong way to install it – the 4-way pin header must be plugged into the 4-way socket, while the 3-way header goes into the 3-way socket.

Installing the LCD

Before installing the LCD, a 16-way SIL pin header must first be fitted to its bottom edge. This is installed from the underside of the PCB with the short pin lengths going through the holes. Check that the header is seated correctly before soldering its pins on the top of the board.

Once the header is in place, cut a short strip of thick cardboard exactly

7mm wide. This cardboard strip is then used as a gauge while the header pins are trimmed using side-cutters – ie, the header pins are trimmed so that their ends are 7mm below the underside of the LCD module's PCB.

Applying power

Before applying power for the first time, make sure that microcontroller IC1 is out of its socket and that the LCD is unplugged. Check the assembly carefully, then apply power and check that there is 5V between pins 14 and 5 of IC1's socket. If there's no reading, check REG1 and the orientation of diode D1.

Assuming you do get the correct reading, switch off and install IC1. The two M3 × 6.3mm standoff mounts for

the LCD module can now be secured to the main PCB using M3 × 6mm screws. That done, plug the LCD into its header socket and secure it to the standoffs at either end using another two M3 × 6mm screws.

Preparing the case

The completed PCB assemblies can now be placed to one side while you prepare the case.

The first step is to drill a 10mm-diameter hole for the DC socket. Fig.3 shows the drilling template and this can either be copied or downloaded in PDF format from the *EPE* website and printed out. Use a small pilot drill to start the hole, then carefully enlarge it to size using larger drills and a tapered reamer.

Fig.4 shows the front-panel artwork (also available from the *EPE* website). This can be used as a drilling template for the four front-panel switches. The holes should all be drilled and enlarged with a tapered reamer to a diameter of 10mm.

Finally, you will have to drill two holes in the base of the case – one to feed through the wiring from GT-511C1R fingerprint scanner (FPS) and another to accept the wiring that runs from the electric door strike to CON2. Note that the wiring to CON2 is fed through the PCB via a hole immediately in front of this terminal block.

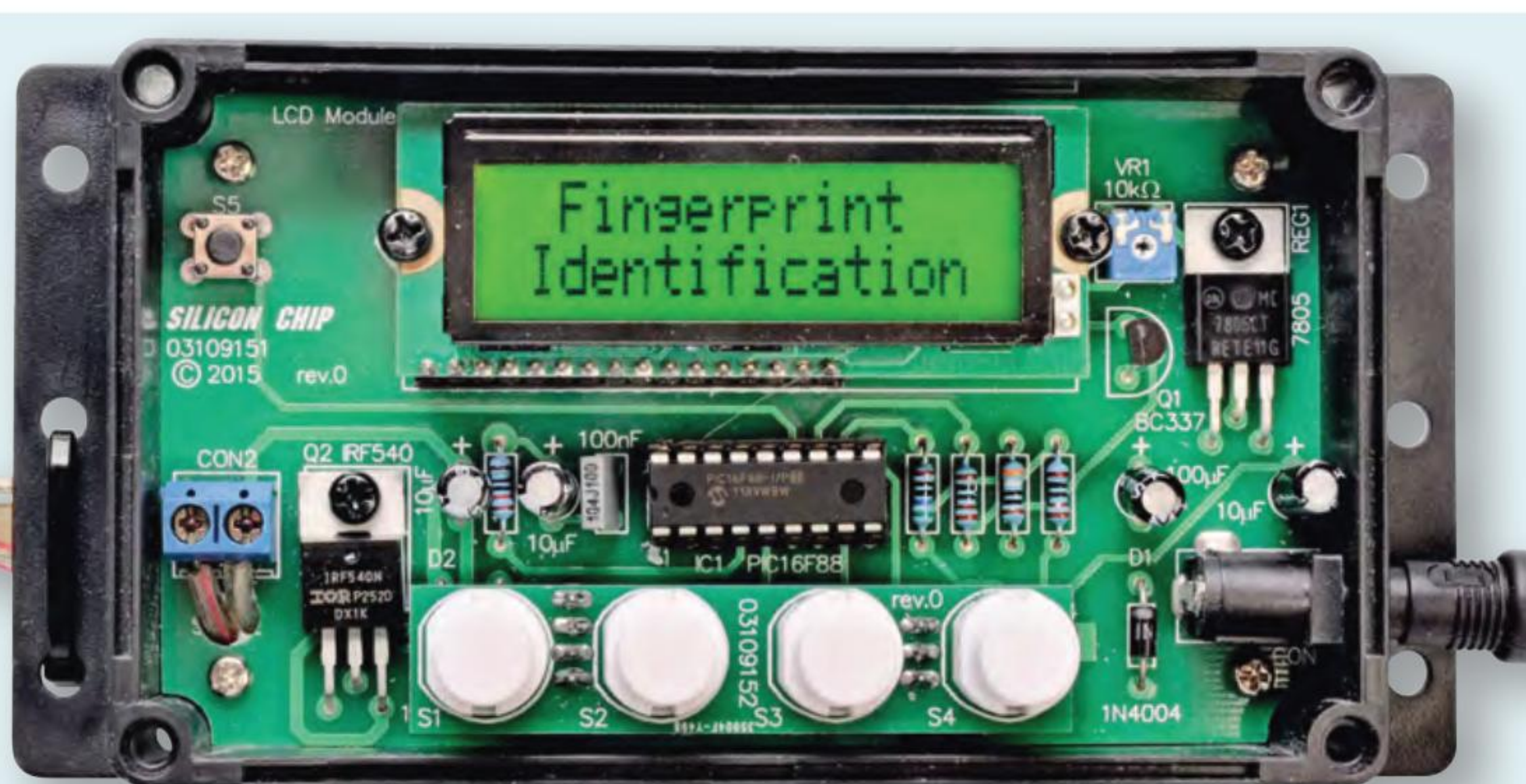
The positions of the two holes in the base are not particularly critical. The hole for the FPS wiring can be drilled so that it will be roughly in-line with the FPS pads on the PCB. The door-strike wiring hole can be positioned in-line with this first hole, so that it will sit more or less behind Q2.

Note that the wiring connector for the FPS is fitted with a JST-SH plug (see parts list). This means that the FPS wiring hole will need to be large enough for the JST-SH plug to pass through.

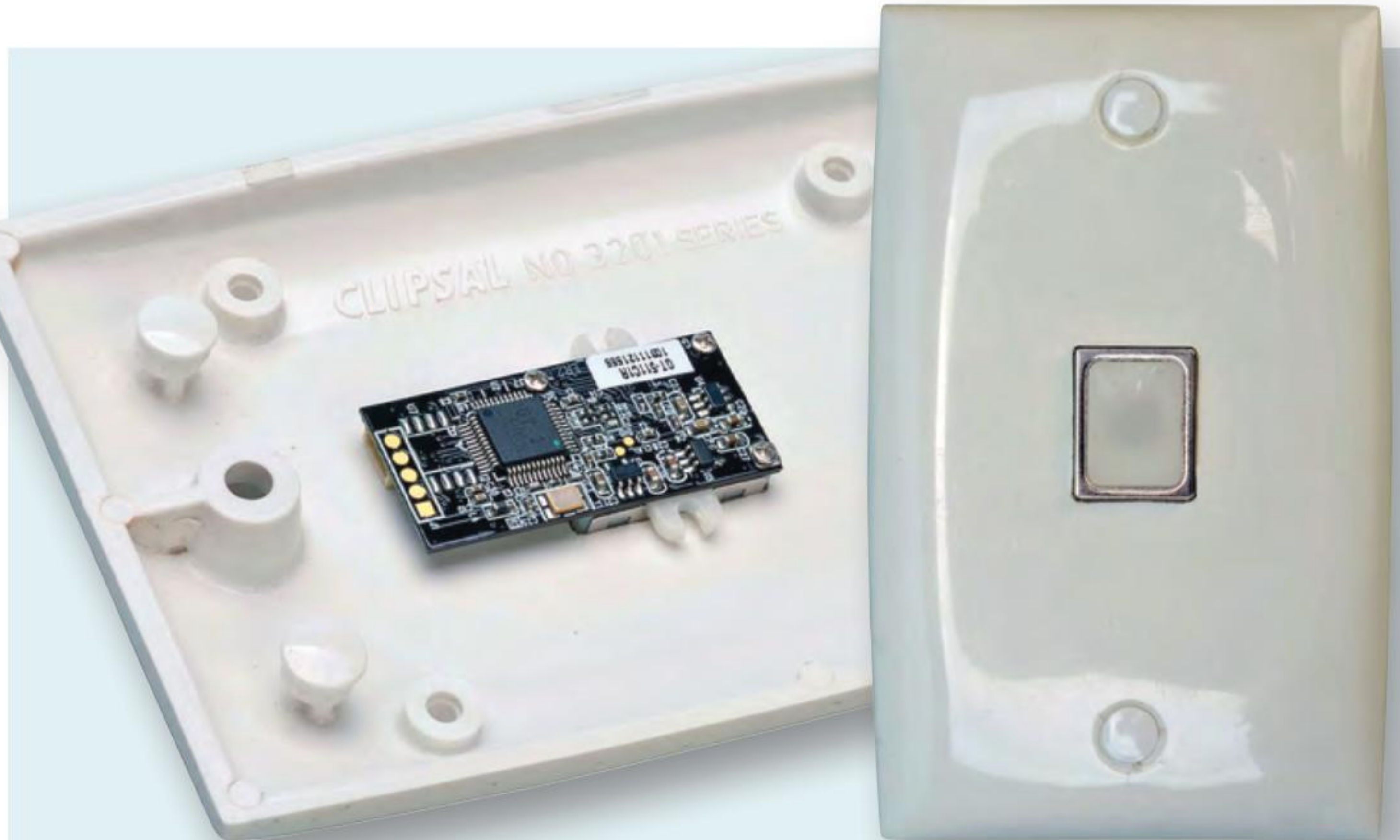
Extending the leads

As supplied, the lead fitted to the JST-SH plug is just 200mm long. It will therefore probably be necessary to extend this lead, depending on the relative positions of the FPS and the control box. We tested the unit with a lead length of 1.2m without any problems.

To extend the cable, you can solder a 4-way rainbow cable or 4-way telephone cable to the FPS pads on the main PCB. The individual wires



The completed PCB assembly is secured inside the case using four self-tapping screws that go into integral stand-offs. The case comes with a transparent lid so there's no need to make a cut-out for the display, although it is necessary to drill holes for pushbutton switches S1-S4.



The GT-511C1R FPS is mounted on the rear of a blank wall-plate. You will need to cut a 16 × 20mm hole to accept the scanning lens. Once it's in place, the module can be secured to the rear of the wall-plate using silicone.

are simply pushed through the holes from the underside of the PCB and soldered on the top side (ie, to the left of D1). The extension cable can then be connected to the JST-SH lead by first sliding short lengths of 2mm-diameter heatshrink tubing over the wires, then soldering the individual leads together. The heatshrink tubing is then slid over the solder joints and shrunk down with a hot-air gun.

Finally, the joins can be secured by sliding a length of 5mm-diameter heatshrink over the whole lot and shrinking it down.

Make sure that the JST-SH cabling is connected with the correct polarity. The black lead on the JST-SH plug is pin 1. The remaining white wires must be connected in the correct order to pins 2, 3 and 4 on the main PCB. Double-check this if using an extension cable,

to ensure that the connections are all still correct.

Final assembly

Now for the final assembly. It's basically a matter of feeding the JST-SH plug and its lead through the corresponding case hole, then sitting the PCB in position inside the case so that it rests on the four integral standoffs at the corners. The PCB is then secured to these standoffs using No.4 self-tapping screws.

The next step is to produce and fit a front-panel label to the case lid. There are a couple of options here, the first being to print the downloaded PDF file onto clear overhead projector film (use film that's suitable for your printer). This label can then be attached to the inside of the lid using clear silicone sealant and the holes

Dataflex/Datapol Labels

- 1) For Dataflex labels, go to:
www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335
- 2) For Datapol labels go to:
www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

for the switches cut out with a sharp hobby knife (note: you will be able to see some of the 'workings' inside the case with this panel).

Alternatively, you can print onto a synthetic Dataflex or Datapol sticky label (see panel) and attach that to the lid after cutting out the LCD hole. The switch holes can then be cut out.

Place the lid to one side after affixing the labels. It's attached to the case later, after the test and adjustment procedure has been completed.

Mounting the FPS

In most cases, you will want to mount the FPS module on a standard blank wall switch-plate (see photos). You will need to cut a 16 x 20mm hole to accept the scanning lens and this should be carefully filed to size so that the module is a tight fit. Once it's in position, the FPS module can be secured in place using silicone sealant.

If the FPS isn't going to be wall-mounted, then it can be mounted in a zippy box.

Testing

Now for the test procedure. First, check that the FPS module is unplugged, then apply power and adjust trimpot VR1 for optimum contrast on the LCD. That

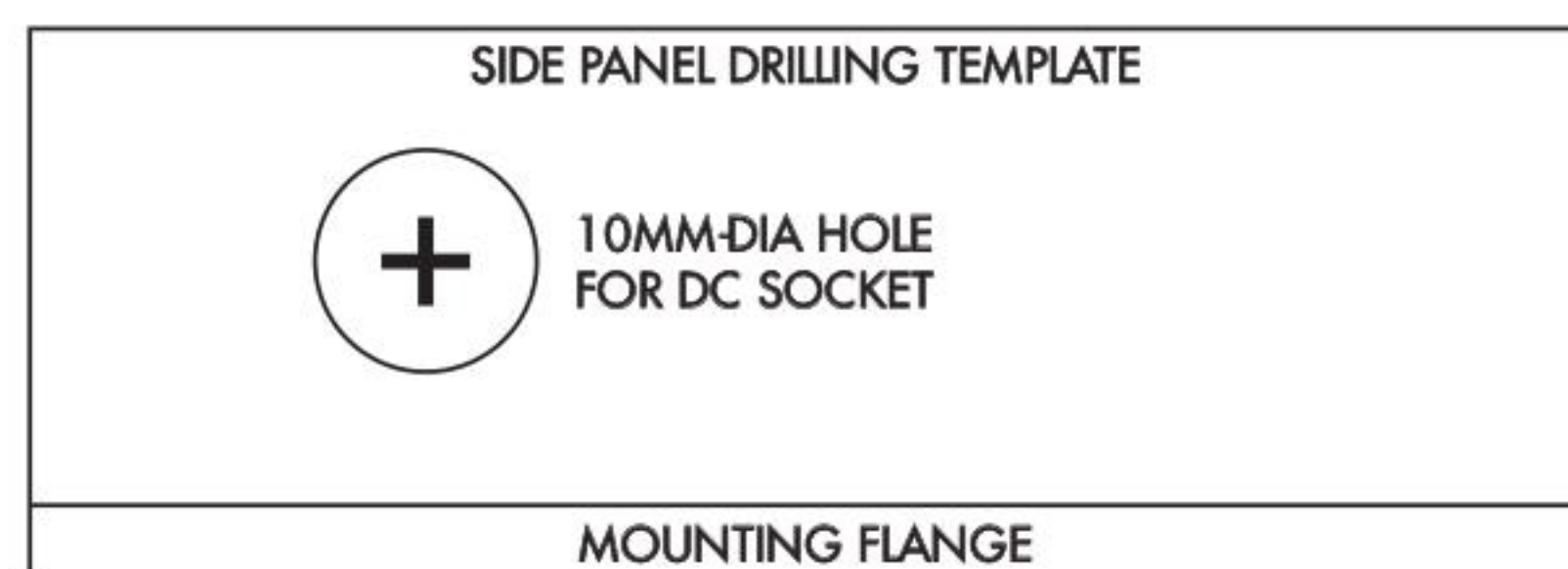
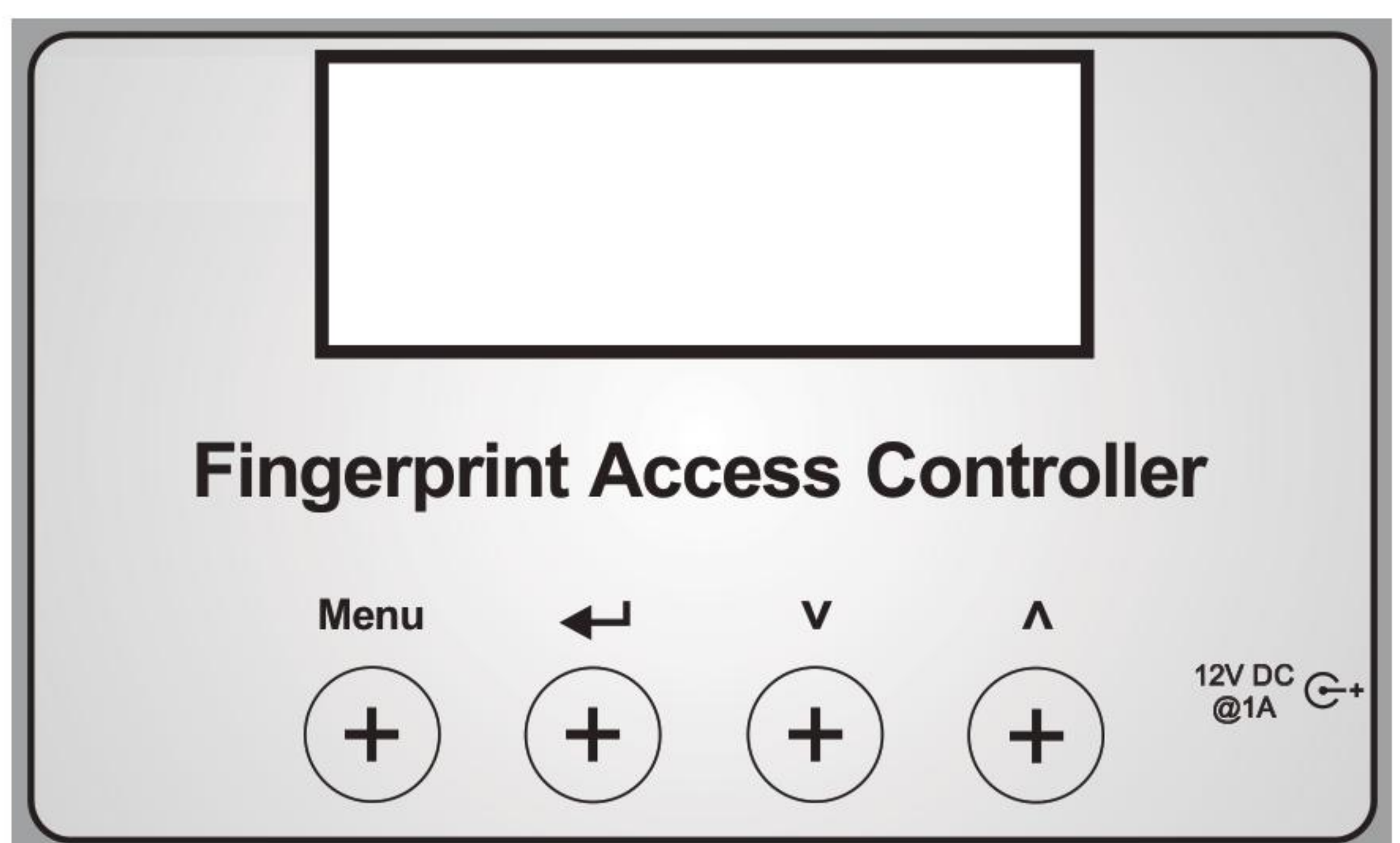


Fig.3 (above): the drilling template for the righthand end panel of the case. A 10mm hole is required to provide access to the DC socket on the PCB.

Fig.4 (right): the full-size front-panel artwork. It can be copied or downloaded as a PDF file from the EPE website and used as a drilling template for the switches. The PDF file can also be used to print a sticky label – see box panel.



Dealing with security errors

If the display shows **Serial No. Error**, this means that the FPS has been changed, either by a prospective intruder hoping to defeat the system or by someone authorised to replace the unit. In the latter case, the security number of the FPS will need to be reloaded in order to get the *Fingerprint Access Controller* working again.

That's done by pressing and holding down switch S5 inside the control unit. This will load the new FPS security number and the switch can be released when the LCD screen shows **Loading FPS Serial No.**

Alternatively, if the FPS has been replaced by an unauthorised person, then it would be wise to delete all enrolments after reloading the FPS serial number and start again.

An **Enrolment Tamper** indication on the display indicates that an enrolment has been made to the FPS using a different controller. Once again, it would be wise to delete all enrolments and start again. Table 2 summarises the security errors.

If the FPS back-lighting doesn't flash and the switches have no effect, the unit has probably halted due to some form of FPS tampering, as detailed in the main article. In that case, the control unit should first be powered down and then powered up again. It's then just a matter of checking if the unit is operating again and that access is possible when a valid fingerprint is scanned.

Table 2: Security errors

Security Error On LCD	What It Means
Serial No. Error Press Enter (Enter returns to the home screen, FPS blue LEDs are off)	The serial number of the connected FPS doesn't match the serial number stored in the control unit. If the FPS swap is legitimate, press S5 in the control unit to read and store the new serial number. If not, delete all enrolments in the new FPS and press S5, then re-enrol valid fingerprints.
Enrolment Tamper Press Enter (Enter returns to the home screen, FPS blue LEDs are off)	One or more enrolments have been made to the FPS using a different controller. Delete all enrolments and start again.

done, switch off, connect the FPS module and apply power again.

When the complete unit is powered up, it will automatically read and store the FPS module's unique serial number in the PIC microcontroller IC1's EEPROM (non-volatile memory). At the same time, the LCD module will display **Loading FPS Serial No.** for a short period before showing the normal home screen which displays **Fingerprint Security Access**.

Once the serial number has been loaded, the FPS should briefly flash its blue back-lighting LEDs once every second. If you then place a finger on the FPS sensor, the blue back-lighting LEDs should light continuously, indicating that a finger has been detected.

At this stage, no fingerprints will be stored in the database and so you will be greeted by an **Access Denied No Enrolments** message.

The next step to perform is to check the switch functions on the

switch PCB. As mentioned previously, these four switches (designated Menu, Return, Down and Up) allow for enrolments and other changes.

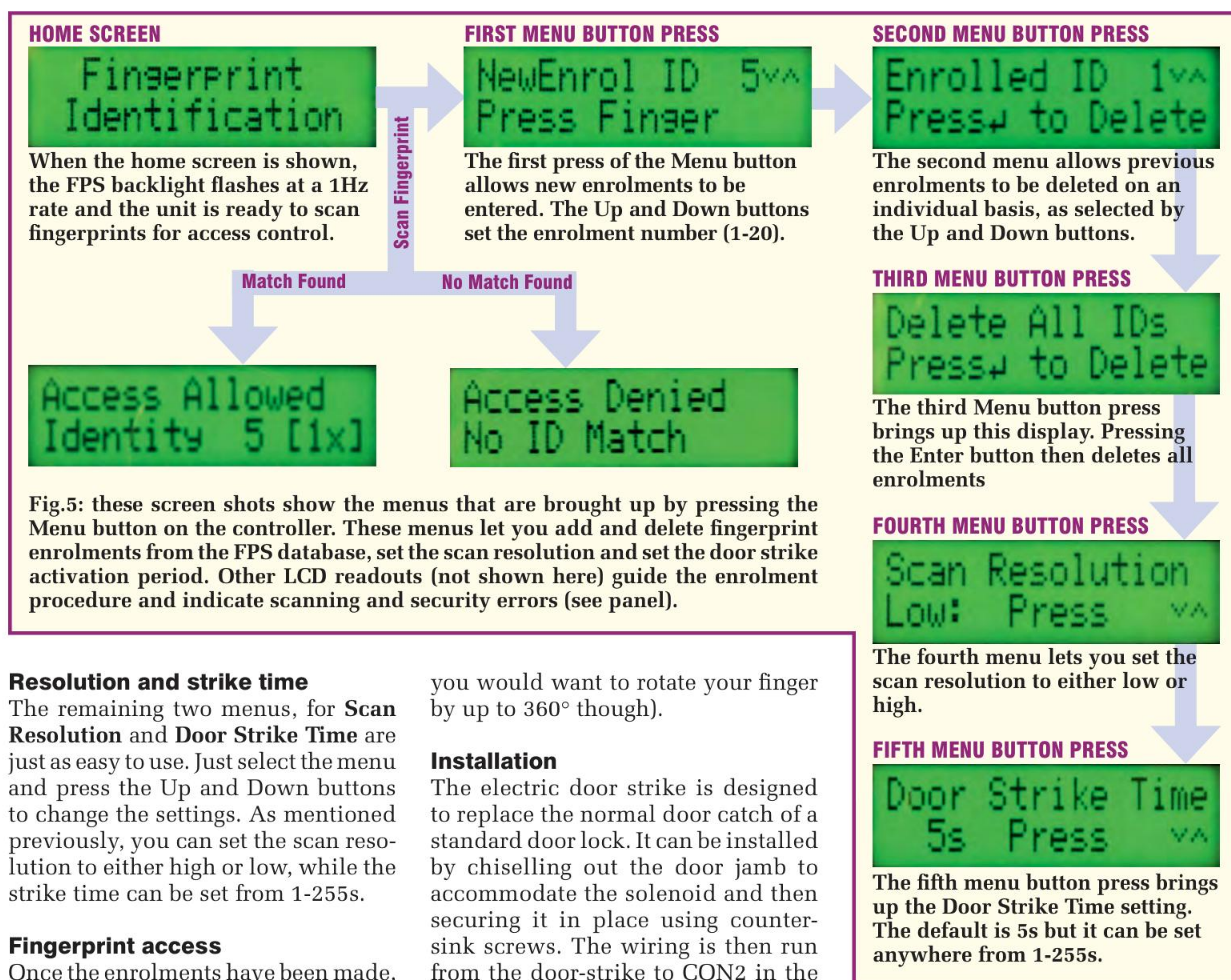
Each time the Menu button is pressed, the display should cycle between the **NewEnrol ID**, **Enrolled ID**, **Delete All IDs**, **Scan Resolution** and **Door Strike Time** menus. Check that this switch functions correctly, then check the operation of the Enter, Down and Up switches. Note that these latter three switches are only effective when menus are opened.

Once you have confirmed that everything is working correctly, fasten the lid in place using the four self-tapping screws supplied with the case.

Entering enrolments

This unit is simple to set up and use. The first step is to enrol fingerprints into the FPS unit and that's done as follows:

- Press the Menu button to bring up **NewEnrol ID** menu – see Fig.5. The controller then checks the enrolments list and the first lowest ID number available will be shown. If the database is full, the LCD will display an **Enrolments Full** message. In that case, you would first need to delete an enrolled ID.
 - Press the Up and Down buttons if you wish to select a different enrolment number to that shown. Note that any previously enrolled ID numbers will not be displayed.
 - Press the Enter button to start the Enrolment process for the displayed ID. This involves taking three separate fingerprint scans which are then merged into the scanner's database.
- During this process, you are first prompted to place your finger on the scanner (**Press Finger**) so that the first fingerprint 'capture' can be made. You are then asked to remove the finger (**Remove Finger**) before being instructed to press the finger on the scanner again. This is then repeated once more, after which **Enrolled** will be displayed on the LCD to acknowledge the enrolment.
- Note that the **Enrolled** message is only displayed for about one second, after which the unit returns to the **Fingerprint Security Access** message.
- Any errors during enrolment are shown on the LCD as **Enrolment Fail**, **Poor Fingerprint** or **Finger Off Error**. If that happens, the unit returns to the start of the enrolment and the process must be started all over again.
- It's not unusual to have to make more than one attempt to achieve a successful enrolment. Note that a dry finger is not always readily recognised and it may be necessary to slightly moisten your finger before placing it on the scanner. In addition, try to place your finger in a similar position on the scanner each time during the enrolment process.
- Deleting enrolments**
- Deleting enrolments is straightforward. All you have to do is press the Menu button to bring up the **Enrolled ID** menu or the **Delete All IDs** menu and press the Enter button. If the **Enrolled ID** menu is selected, only the displayed enrolment ID will be deleted when the Enter button is pressed and this can be selected using the Up and Down buttons.



Resolution and strike time

The remaining two menus, for **Scan Resolution** and **Door Strike Time** are just as easy to use. Just select the menu and press the Up and Down buttons to change the settings. As mentioned previously, you can set the scan resolution to either high or low, while the strike time can be set from 1-255s.

Fingerprint access

Once the enrolments have been made, the unit is ready for use. When a finger is placed on the scanner and access is allowed, the LCD shows an 'in brackets' guide listing how many times the user's fingerprint has been compared against the enrolments in the database (this is shown following the ID number). A [1x] display means that the fingerprint was successfully compared with the database on the first attempt.

Up to six complete fingerprint captures and comparisons with the database are allowed before it displays a **No ID Match** reading. When that happens, the user can remove and replace his finger on the scanner and try again.

Note that the low-resolution setting may give more reliable matches than the high-resolution setting. Note also that the FPS will identify a fingerprint that's rotated compared to the original enrolled version. In fact, the fingerprint can be rotated by up to 360° (Editor's note: we are not to sure why

you would want to rotate your finger by up to 360° though).

Installation

The electric door strike is designed to replace the normal door catch of a standard door lock. It can be installed by chiselling out the door jamb to accommodate the solenoid and then securing it in place using counter-sink screws. The wiring is then run from the door-strike to CON2 in the control box.

The wiring polarity to the door strike is not important.

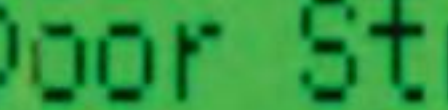
As stated previously, the FPS module would normally be fitted to a blank switch-plate. This assembly would then be mounted on the access side of the door, close to the door handle. Be sure to keep it well away from any 230VAC mains cabling or wall switches.

You must waterproof the scanner if the unit is to be located outdoors. That can be done by mounting the switch-plate on a covered switch box and running a thin bead of silicone around the outside edge of the scanning lens. Don't get any silicone on the lens though, otherwise it won't work.

The control box can be mounted adjacent to the door-strike on a wall inside the secured area. Alternatively, if you want to be able to see the LCD when using the scanner, you could arrange to have the control unit mounted behind a smash-proof

The fourth menu lets you set the scan resolution to either low or high.

FIFTH MENU BUTTON PRESS



The fifth menu button press brings up the Door Strike Time setting. The default is 5s but it can be set anywhere from 1-255s.

glass window, with the LCD facing outside.

On the other hand, if security isn't vital, the control box could be located with the scanner. However, it would be a good idea to remove the switch PCB to prevent the unauthorised addition of fingerprint enrolments.

Bezel lamp

One option that you might like to consider is to mount a 12V bezel lamp on the wall-plate adjacent to the FPS module. This lamp can then be wired in parallel with the door strike (ie, by connecting it to CON2), so that it lights whenever the door strike is powered.

The lamp bezel can use either a filament bulb or an LED. **It must be wired via a 100mA fuse located in the control unit.** That way, if someone pulls the lamp bezel out and tries to activate the door strike by feeding 12V back down the lamp wires, the fuse will blow and prevent access.

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Win a Microchip PIC32 Ethernet Starter Kit

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a PIC32 Ethernet Starter Kit II from Microchip.

The PIC32 Ethernet Starter Kit II (DM320004-2) provides the easiest and lowest-cost method to experience 10/100 Ethernet development with PIC32 microcontrollers. Combined with Microchip's free TCP/IP software, this kit gets your project running quickly. The PIC32 microcontroller has an available CAN2.0B peripheral and USB host/device/OTG. This starter kit features a socket that can accommodate various 10/100 Ethernet transceiver (RJ-45) PHY daughter boards for prototyping and development.

This evaluation kit includes the PIC32 Ethernet Starter Kit II Development Board, the LAN8740 PHY daughter board, an Ethernet patch cord, and two USB cables (Standard-A to Micro-B and a Standard-A to Mini-B). The board features a Mini-B USB port for debugging, a Standard-A USB port for the embedded host, and a Micro-AB USB host/device/OTG port.

The starter kit is preloaded with demonstration software for the user to explore the features of the PIC32. It is also expandable through a modular expansion interface, which allows the user to extend its functionality. The starter kit also supplies on-board circuitry for full debug and programming capabilities.



HOW TO ENTER

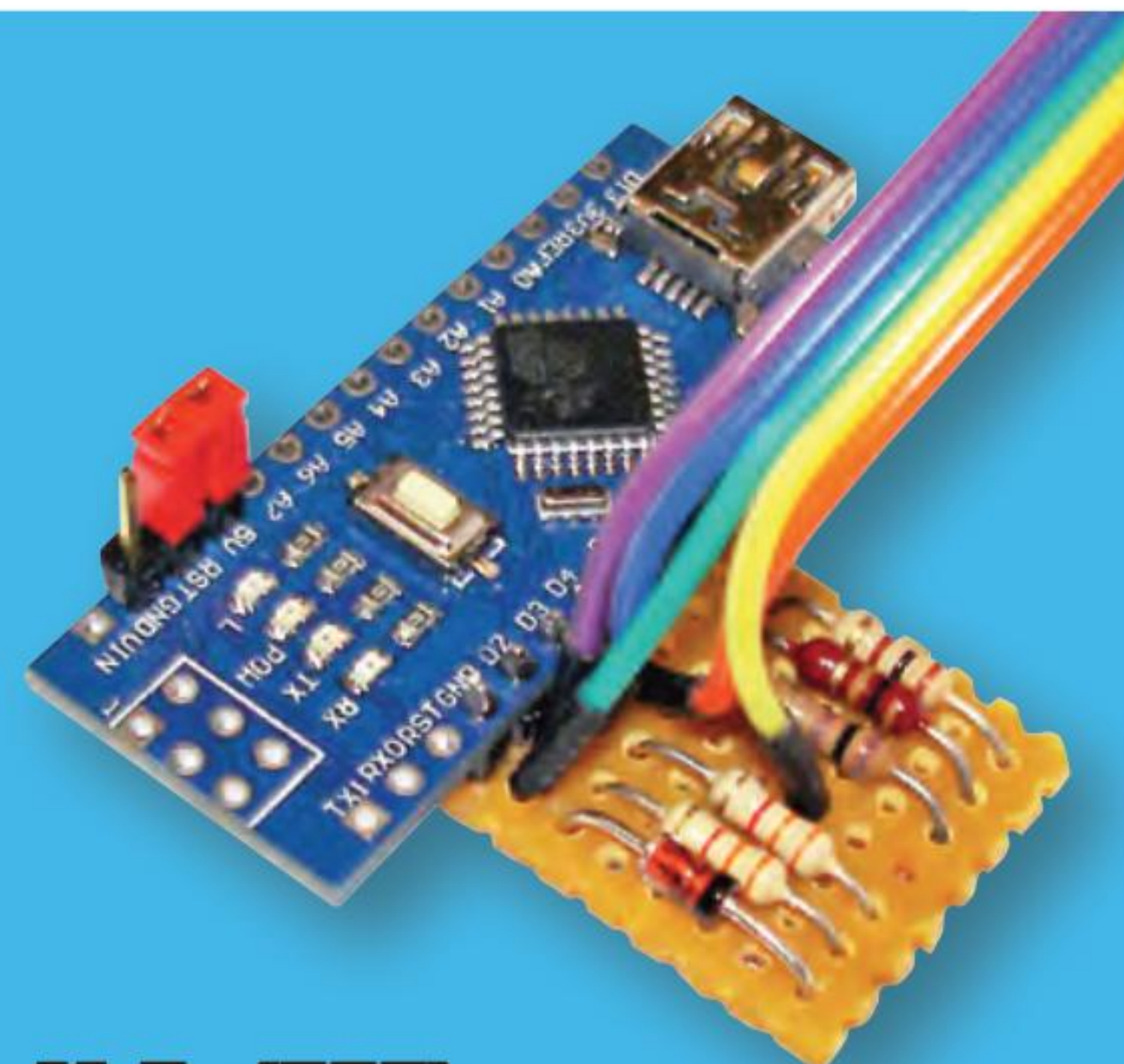
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CLOSING DATE

The closing date for this offer is 30 November 2016.

Cheap programmer for the PIC32 microcontroller

By Robert Rozée, M.E. (EEE)



Want to build a recent project that uses a PIC32? Great...! but the prospect of programming a PIC32 can initially seem daunting. This minimal programmer will upload firmware into a PIC32 quickly and simply at very low cost.

WITH THE DEMISE of parallel and 'real' serial ports on PCs, getting code into Microchip's PIC processors has in recent years become more complicated and expensive. Way back in the 1990s, you only needed a few resistors and a transistor to build a low-cost PIC programmer, and hobbyists around the world spent many a joyful hour creating interesting gadgets with these little microcontrollers.

Sadly, those simple programmers no longer work with today's USB-to-serial bridge adapters and a PICKIT 2 or PICKIT 3 became essential. Then there is the large and somewhat complex MPLAB X IDE (400MB download) needed to drive Microchip's programmer.

At first sight, these might be somewhat daunting requirements for a user looking to program a single PIC for the first time. Compare this to the popular Arduino platform. Every Arduino board comes with a serial bootloader

pre-installed, hence code can be uploaded directly via a serial or USB port without the need for a specialised programmer. The software to write, compile and upload this code (the Arduino IDE) is 'only' an 80MB download. Which was great – for a while.

The Backshed approach

Now, a group of intrepid members from 'The Backshed Forums' has set about trying to create a cheap and simple route.

The end result

At the end of this (somewhat lengthy) effort lay a new set of extensions to **pic32prog**, an existing open source (GPL) command-line utility written and maintained by Serge Vakulenko. It works with a range of commercial PIC programmers – including the PICKIT 2 (but not 3). The latest release of **pic32prog** is now also able to use

an Arduino Nano, using a protocol dubbed 'ascii ICSP'. Together with a few resistors and a 3.3V zener diode, this is sufficient to upload firmware to a PIC32. The total cost? Less than that of a single PIC32MX170 chip.

The Arduino hardware and 'ascii ICSP' protocol are needed as an intermediate step. This is because, even though a modern PC has lots of computing power, limitations in the way USB is implemented prevent direct access to the control pins (RTS, CTS, DSR, DTR) of a USB-to-serial bridge at any reasonable speed.

Early attempts that connected directly between serial port pins and the target PIC32 resulted in programming times of several hours or extreme unreliability, whereas with an Arduino Nano in between, this time is cut to just a few minutes.

The 'ascii ICSP' protocol is very simple, accepting single-character ASCII commands from a host computer (running **pic32prog**) and converting these into the clock (PGC) and data (PGD) signals needed to program a PIC32. Lower-case letters d, e, f, and g cause clocked output of the bit pairs 00, 01, 10, and 11 respectively, while upper-case letters D, E, F and G clock out the same pairs, then read back one bit.

Other commands carry 4-bit pairs encoded as a single letter, assert and release the reset (MCLR) pin and turn

The PIC32 Processor Family

The PIC32 family of processors, made by Microchip Technology Inc, are powerful 32-bit system-on-chip (SoC) devices containing everything required to implement quite complicated computers that are as powerful as the first IBM PCs. This from a chip that is available in a 28-pin DIP, costs less than US\$5, and can run from a pair of AA cells.

A number of *EPE* projects in recent years have made use of PIC32 devices, including: the *GPS Tracker* and *Nixie Tube Clock*.

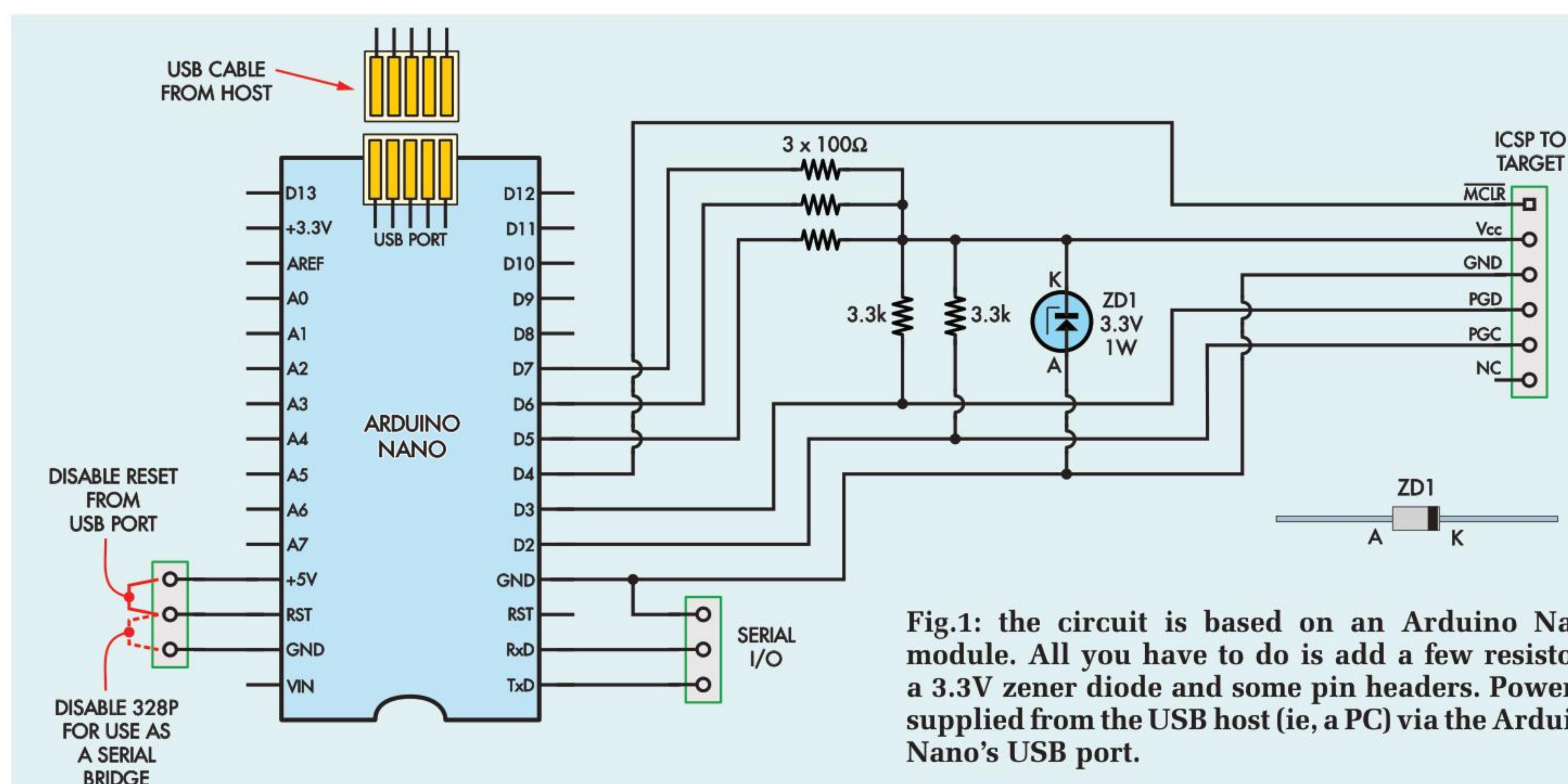


Fig.1: the circuit is based on an Arduino Nano module. All you have to do is add a few resistors, a 3.3V zener diode and some pin headers. Power is supplied from the USB host (ie, a PC) via the Arduino Nano's USB port.

LOW-COST PIC32 PROGRAMMER USING AN ARDUINO NANO

on/off the 3.3V supply to the target PIC32. Between PC and Arduino, serial communications occur at a brisk 115,200 baud.

Hardware

The hardware is simple and cheap, the most expensive part being an Arduino Nano, widely and cheaply available via eBay. Three 100Ω resistors and a 3.3V zener diode create a switchable 3.3V supply for the PIC32 being programmed, capable of delivering up to 50mA ($(5V - 3.3V) / 33\Omega$) to the device. This load is shared across three pins on the Arduino, each capable of delivering 20mA.

Two more resistors (3.3kΩ) provide pull-ups for open-collector outputs that drive the two programming pins on the target PIC32 – these are PGC (clock) and PGD (data). These two pull-ups go to the 3.3V supply – while the Arduino Nano is a 5V device, most of the PIC32 pins should never have over 3.3V applied. No pull-up is fitted to the open-collector MCLR (reset) output, because a 10kΩ pull-up should normally be present at the PIC32 end.

In operation, programming data is exchanged with the PIC32 in a 4-phase cycle. In phases 1 and 2, data (2 bits) is written to PGD. In phase 3, the direction of PGD is reversed to allow a single data bit to be read back from the

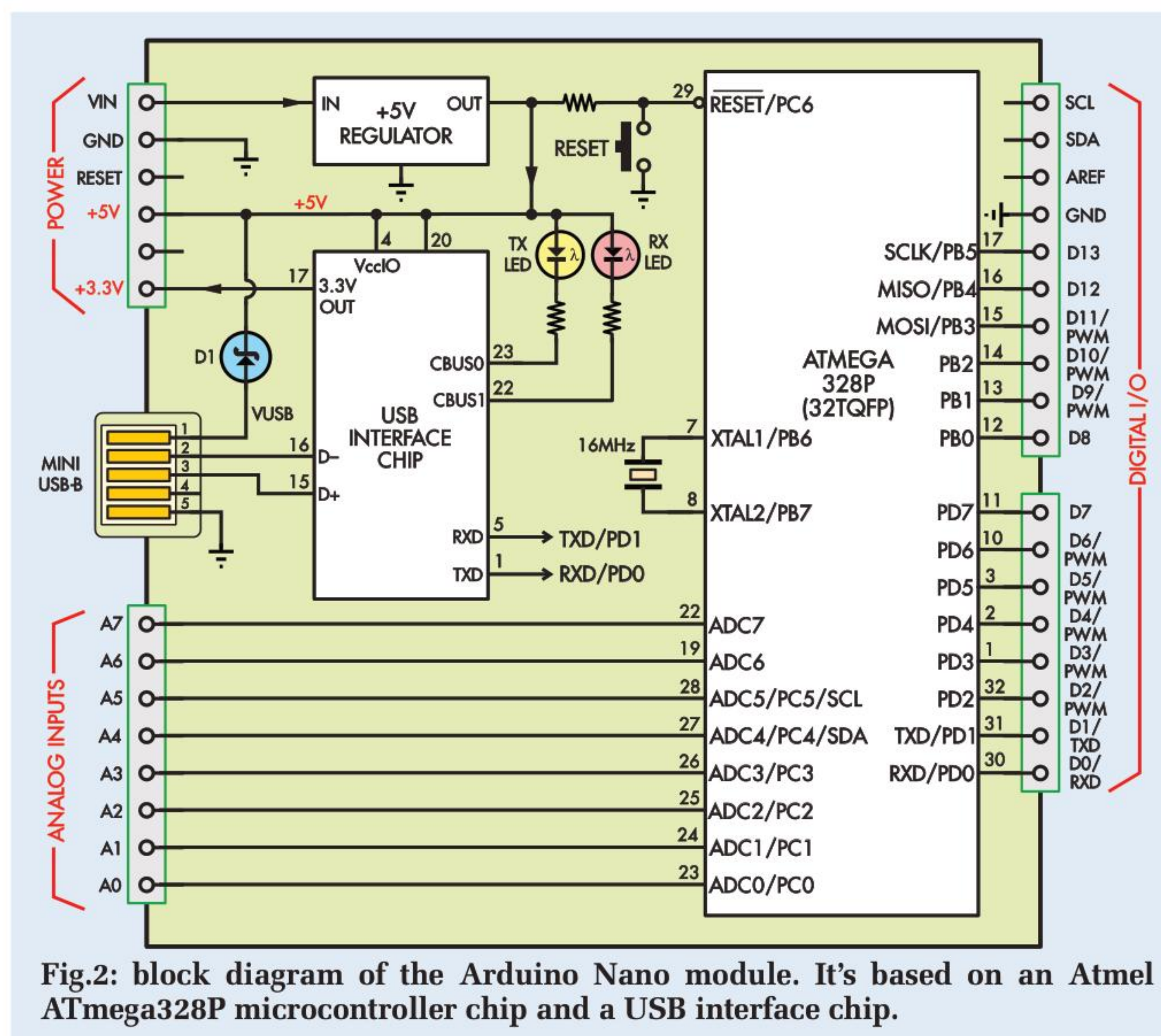


Fig.2: block diagram of the Arduino Nano module. It's based on an Atmel ATmega328P microcontroller chip and a USB interface chip.

PIC32, then in phase 4 the direction of PGD is reversed again.

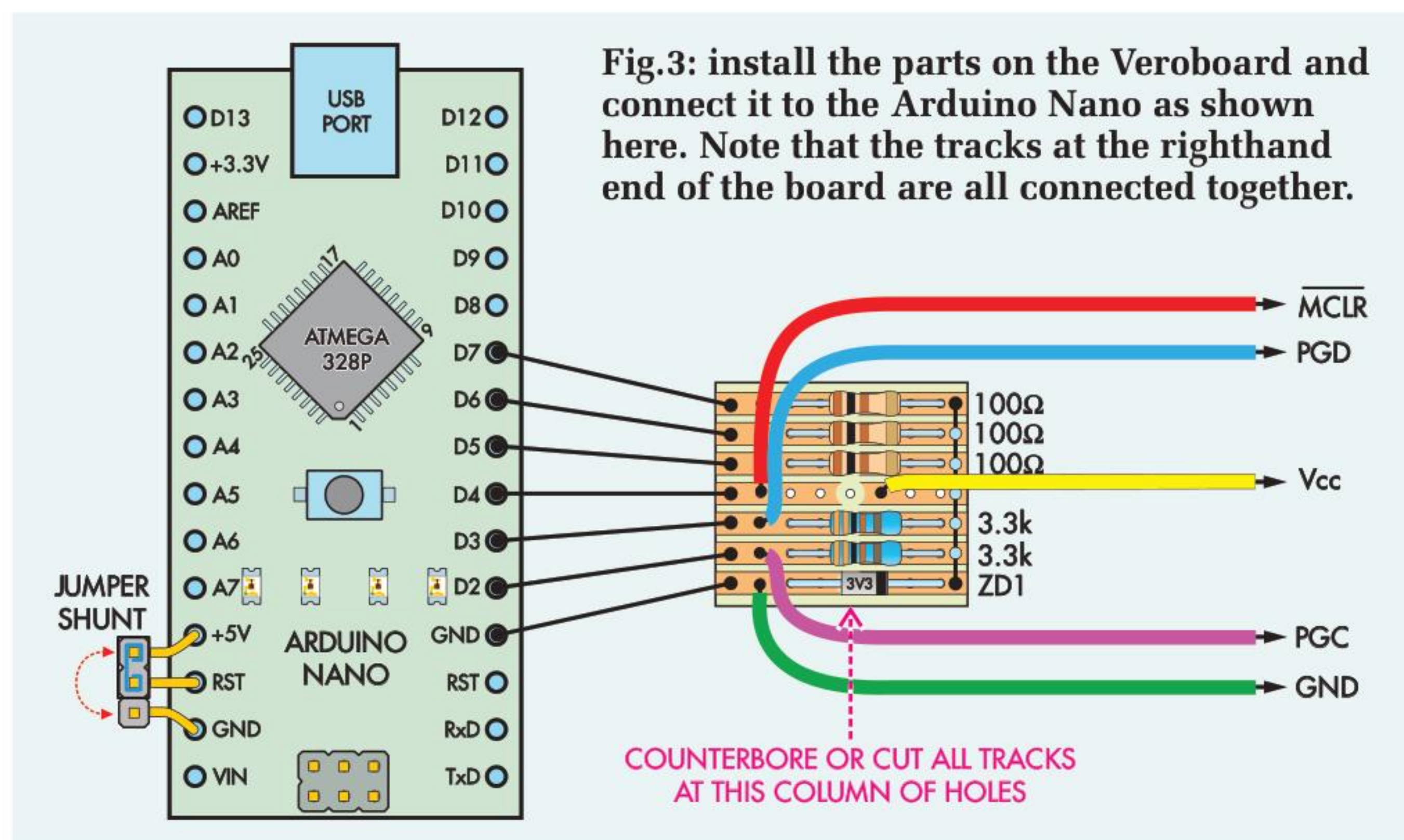
Building it

The circuit is built on a small section of Veroboard attached to the side of the Nano, with a 5-way cable running

up to a standard 6-pin ICSP plug. If desired, an LED and a 3.3k Ω series resistor can be connected across the 3.3V zener diode to show when the supply is turned on.

A 3-way header should also be fitted to the Arduino Nano board to allow

Constructional Project

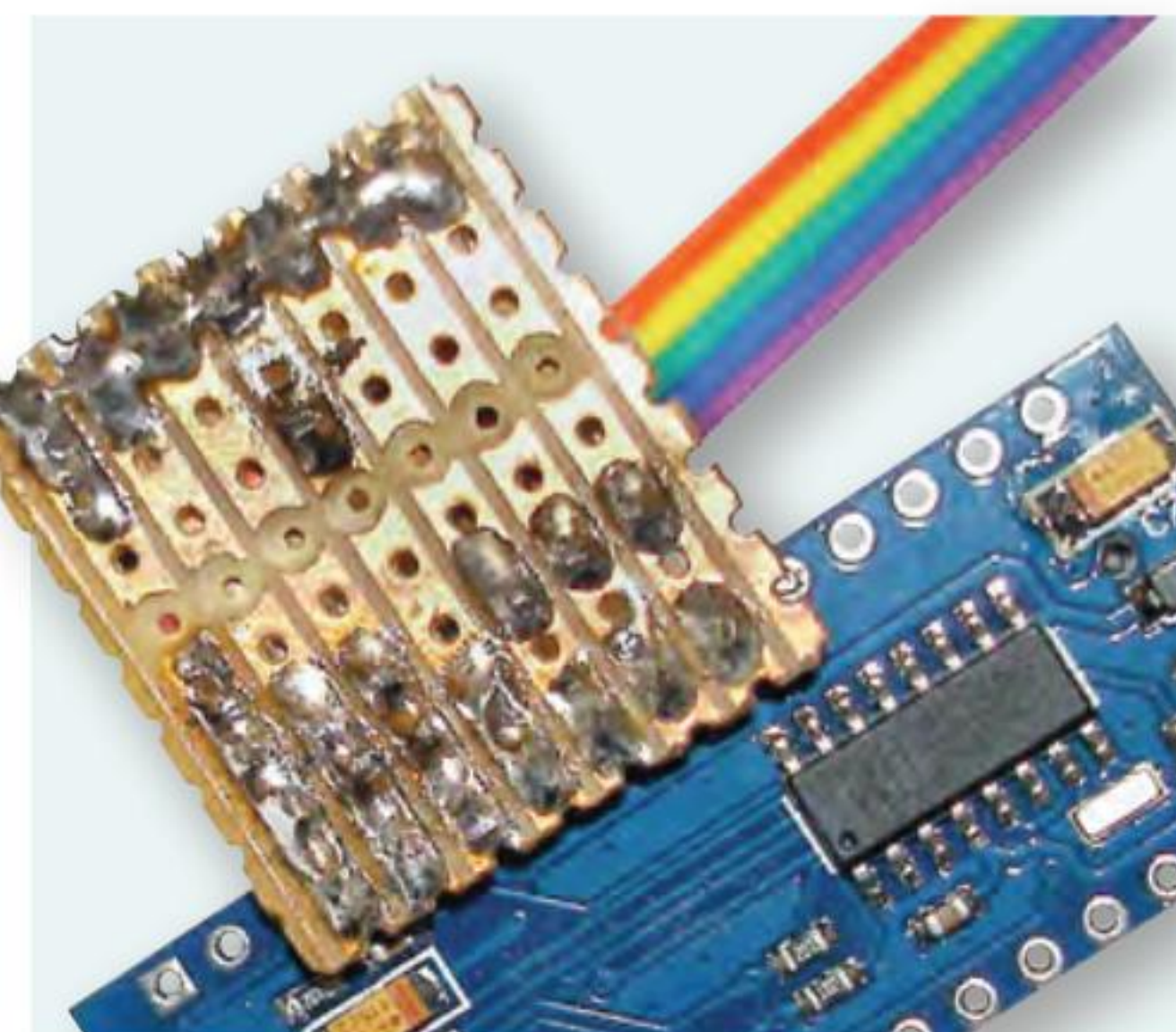


linking its reset pin to ground or +5V. If the Arduino's reset pin is linked to ground, the onboard ATmega328P processor is disabled and the board can be used as a simple USB-to-serial bridge (via the 'serial I/O' connector shown on the schematic). If reset is linked to +5V, the firmware on the Arduino is protected from being overwritten and the programmer will be detected more quickly when **pic32prog** is launched. **Do NOT install a jumper on these pins yet.**

Note: do not press the onboard reset button while the reset pin is linked to +5V, as doing so will short the USB port's +5V output to ground.

Software

The only software required is the **pic32prog.exe** executable itself (versions 2.0.174 or later). You can download this file from the **pic32prog** source repository, which is at the GitHub:



The tracks on the underside of the Veroboard must all be cut as shown in this photograph.

<https://github.com/sergev/pic32prog>
<https://github.com/sergev/pic32prog/blob/master/pic32prog.exe?raw=true>

Note: the *second* link goes direct to the Win32 executable. Mac OS X and Linux versions are also available.

Drivers for the Arduino's USB-to-serial bridge may also be required for Windows XP and earlier. In the case of Chinese clones of the Arduino Nano currently available on eBay, it's likely that the bridge device used will be a CH430G, with drivers available from the manufacturer: www.wch.cn/download/CH341SER_ZIP.html

The Arduino IDE is not required for loading the 'ascii ICP' firmware onto the Arduino Nano, as this function is performed by **pic32prog** internally. Once the USB drivers have been installed, simply open a command window at the folder where **pic32prog** is located. With the Arduino attached to a USB port but no target PIC32 connected, type:

```
pic32prog -d ascii:com5 -b3
```

where com5 is the serial port assigned to the Arduino, ascii is the name for the class of programmer ('ascii ICSP'), and -b3 tells **pic32prog** to upload the 'ascii ICSP' firmware to the attached Arduino. This should display a message saying that firmware is being uploaded to the Arduino and will complete in a few seconds:

```
C>pic32prog -d ascii:com5 -b3
Programmer for Microchip PIC32
microcontrollers, Version 2.0.147
Copyright: (C) 2011-2015 Serge
Vakulenko
(ascii ICSP coded by Robert
Rozee)
57600 baud ... synchronized
```

Typical programming session

```
C>pic32prog -d ascii:com5 mm47b32.hex
Programmer for Microchip PIC32 microcontrollers, Version 2.0.174
Copyright: (C) 2011-2015 Serge Vakulenko
(ascii ICSP coded by Robert Rozee)
```

```
Adapter: . OK1 OK2 - ascii ICSP v1E
Processor: MX170F256B
Flash memory: 256 kbytes
Boot memory: 3 kbytes
Data: 258692 bytes
Erase: (90mS) done
Loading PE: 1 2 3 4 (LDR) 5 6 7a (PE) 7b 8 v0301
Program flash: ##### done
Program boot: ##### done
Verify flash: ##### done
Verify boot: ##### done
Program rate: 2086 bytes per second
```

```
total TDI/TMS pairs sent = 3147141 pairs
total TDO bits received = 459064 bits
total ascii codes sent = 987417
total ascii codes recv = 157828
maximum continuous write = 452 chars
O/S serial writes = 95940
O/S serial reads (data) = 14354
O/S serial reads (sync) = 10
XferFastData count = 58902
10mS delays (E/X/R) = 9/0/0
elapsed programming time = 2m 06s
```

Where to buy parts

A kitset for this project is available from Rictech: <http://www.rictech.nz/products/9/ASCII-ICSP-kit-for-Micromite-and-other-PIC32-MCU-s>

A blank PCB is also available: <http://www.rictech.nz/products/10/ASCII-ICSP-blank-PCB>

Signature = 1e950f Device = ATmega328P

#####

Firmware uploaded to 'ascii ICSP' adapter OK

If you see a row of dots after the '57600 baud' and a failure message, try repeating the process but this time press the Arduino's reset button while the dots are being written. If this also fails, try using -b1, -b2 or -b4 to select different Arduino bootloader baud rates. The vast majority of Arduino Nanos use a bootloader baud rate of 57,600, but there may be a few that use something different.

Note that the above step to upload the 'ascii ICSP' firmware to the Arduino Nano need only be performed once. **You should then install a jumper between the reset and +5V pins.** You are then ready to upload firmware to your PIC32.

Using it

Place the firmware you want to upload in the same directory as **pic32prog** and open a command window at that location. Connect the target PIC32 to the programming hardware (Arduino).

The target PIC32 needs to have all its ground pins connected together, all V_{DD} pins connected, a suitable capacitor between the Vcap pin and ground, and MCLR pulled up to V_{DD} via a 10kΩ resistor. It is essential that no ground or V_{DD} pins be left disconnected.

An example schematic for the PIC32MX170B 28-pin DIP is shown in Fig.4, including the ICSP serial terminal connectors. The capacitor at Vcap should be a low-ESR type, such as chip ceramic or tantalum. If ceramic, the capacitor can be a 10µF part.

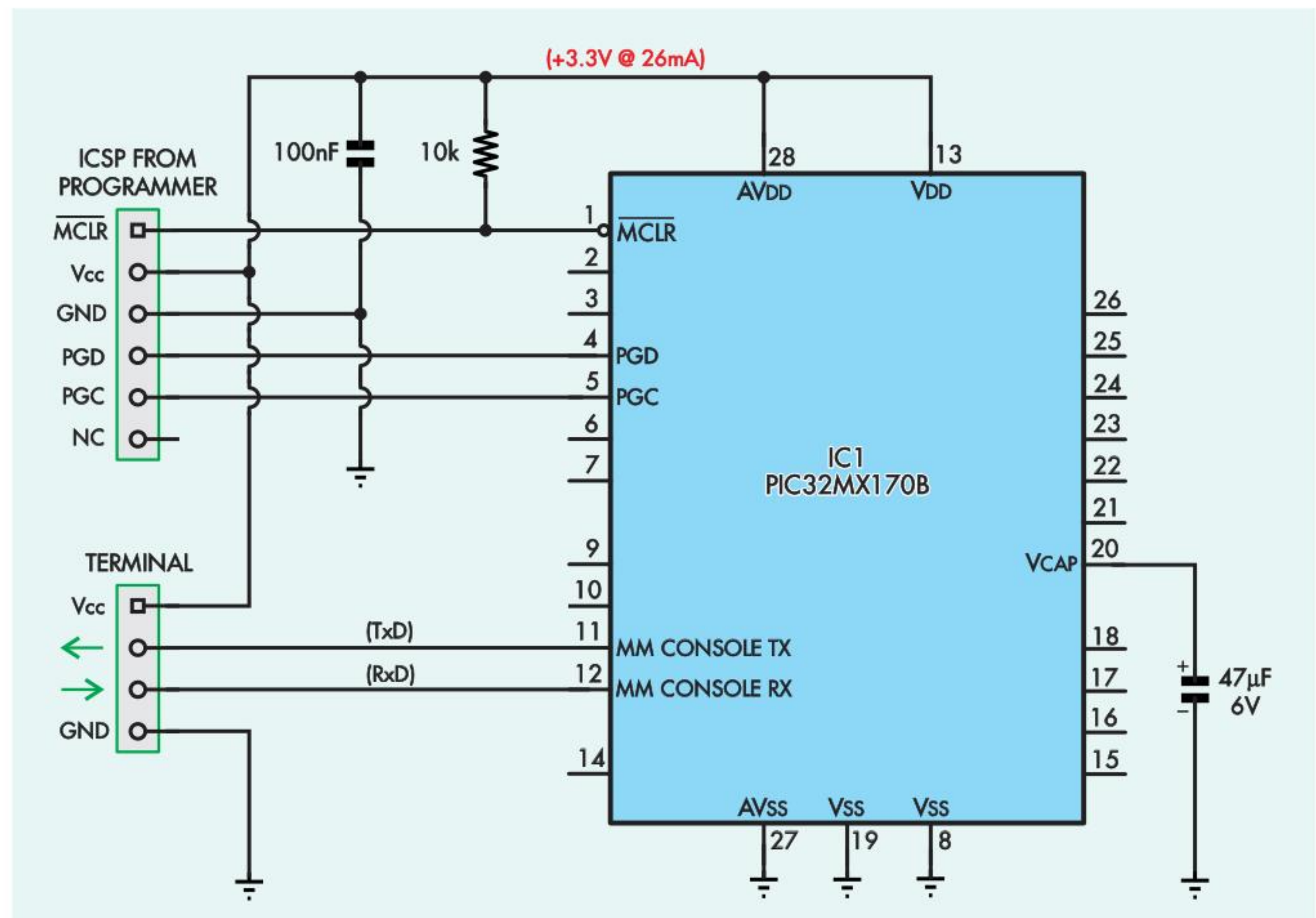


Fig.4: before programming, the target PIC32 microcontroller needs to be wired in a manner similar to this example PIC32MX170B (check the pin connections for your particular PIC micro).

To upload the PIC32 firmware, type:

```
pic32prog -d ascii:com5 filename.hex
```

where filename.hex is the name of the firmware file. The programming hardware handles supplying power to the target PIC32, turning the 3.3V supply on before commencing programming and turning it off when completed.

Programming should take a few minutes, after which you can disconnect the programmer from your PIC32.

On rare occasions, **pic32prog** can throw an error during programming. This is usually due to spurious behaviour in the target PIC32, caused by electrical noise from the PC's power supply (especially if it's a laptop). If

this happens, just reprogram the device and the error will almost certainly not re-occur. Laptop computers can produce more electrical noise when running on AC power, so running off the battery may be prudent if issues arise.

Conclusion

The combination of **pic32prog** and Arduino Nano provides a simple and cheap method for programming a PIC32 chip, albeit a bit more slowly than the PICkit 2/3 and without the integrated support in the MPLAB X IDE.

Acknowledgements

- 1) 'ascii ICSP' protocol and hardware designed by Robert Rozée.
- 2) 'bitbang.c' extension for **pic32prog** written by Serge Vakulenko and Robert Rozée.
- 3) The Backshed Forums: http://www.thebackshed.com/forum/forum_topics.asp?FID=16
- 4) Full details of the 'ascii ICSP' protocol are available in the file ICSP_v1E.ino at: <https://github.com/sergev/pic32prog/tree/master/bitbang>
- 5) PIC32 programming details are from: 'PIC32 Flash Programming Specification' (60001145N.pdf)

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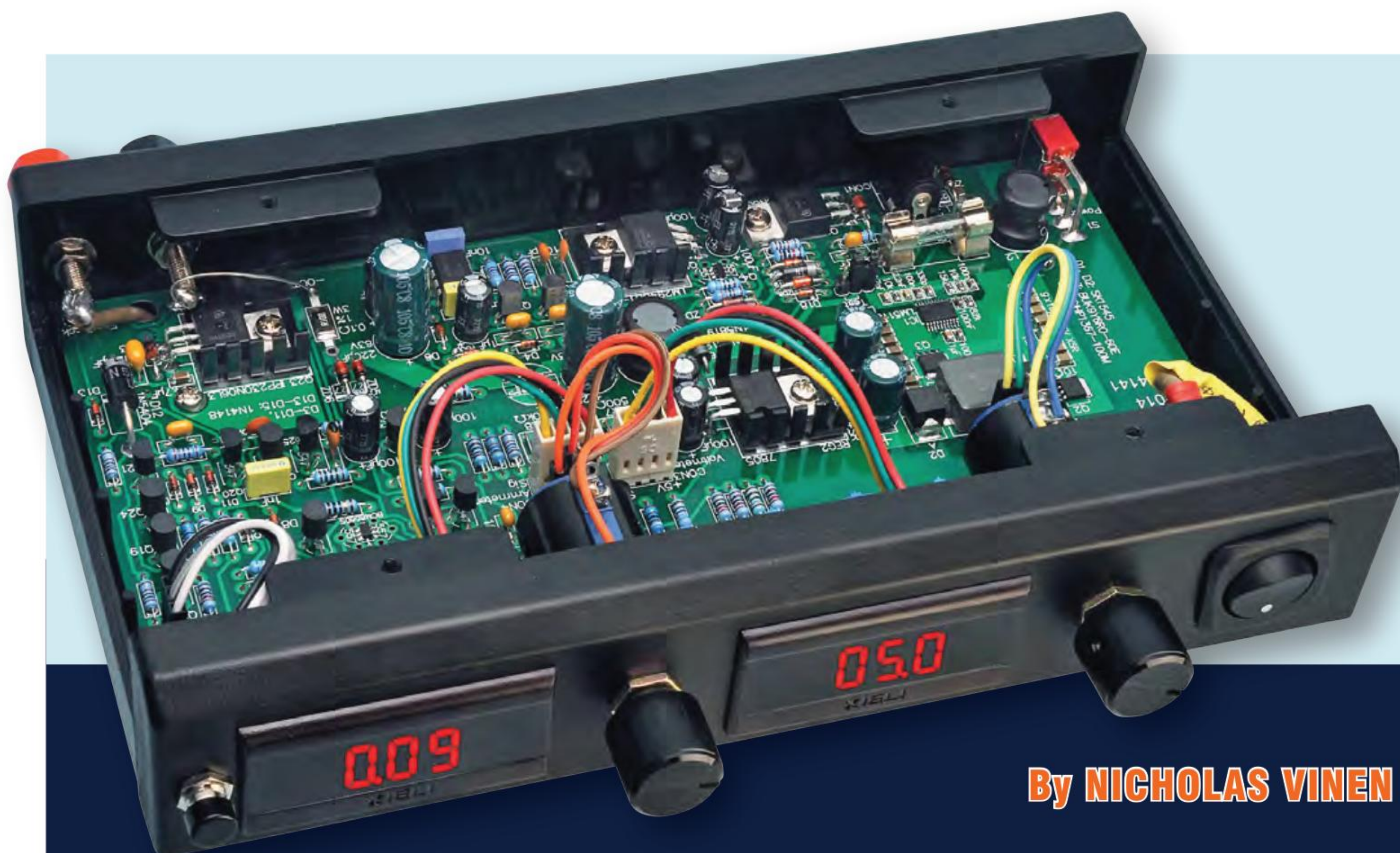
Useful batch files – open a command window and list serial ports

When using command-line utilities like **pic32prog** under Windows, there are a couple of batch files that are extremely useful to have sitting in the same folder. The first is a 'command.bat' file, which, when double-clicked in a folder, will open a command window at that location. The 'command.bat' file is as follows:

```
@prompt $n$g  
@cmd
```

The other useful batch file to have around is 'ports.bat' to list the available serial ports on a Windows PC. While there are more complicated solutions, the simplest means of obtaining this information is from the Windows registry using the following lines within the 'ports.bat' batch file:

```
@reg query HKLM\hardware\devicemap\serialcomm  
@pause
```

By **NICHOLAS VINEN**

Hybrid Switchmode / Linear Bench Supply – Part 3

In this third and final instalment on our 40V/5A DC input bench supply, we take the completed PCB and fit it into the case, along with the chassis-mounting hardware and wiring. We also answer some reader questions about the supply.

OVER THE LAST two months, we have described the operation of our new bench power supply and given the construction details for the PCB. This supply is somewhat unusual in that it runs off a 12-24V input such as a 12V battery or old PC or laptop power supply. It also combines a switchmode buck/boost circuit with a linear regulator to give a wide output voltage range, low noise and fast-acting current limiting.

It's built into a case from Altronics which will be supplied with two pre-fitted LED panel meters for dual metering, ie, simultaneous voltage and current read-out. The voltage and

current are adjustable in 0-40V and 0-5A ranges using multi-turn pots for accuracy. There is also a pushbutton to view the current-limit setting to make it easier to adjust. Since the current limiting is linear in nature, the supply can be used as a voltage or current source.

Now let's go over the final steps to complete and test the power supply.

Preparing the panel meters

In addition to trimming the leads and fitting plugs to suit the connectors on the PCB, we need to tweak the two LED panel meters slightly. This is best carried out by first removing them from

the front of the case, which is done by squeezing the clip on one side and then pushing that side forward until it pops out the front. You can then squeeze in the clip on the other side and remove the unit.

The actual panel meter is inside a plastic housing with a rear plate that's held on by four more clips, two on either side. Gently push these in with the tip of a flat-blade screwdriver; you don't want to snap the plastic. Once you've popped one side up, the rear panel should then come off easily and you can pull the PCB assembly out.

The first thing to do is remove the short circuit between pins 2 and 3 of

the header connector. This can be done by simply running a hot iron between them a couple of times, taking care not to damage any of the surrounding components. Do this for both panel meters.

We also need to change the position of the decimal point on one panel meter. By default, they read up to 199.9, which suits us for voltage, but for current we need it to read up to 19.99, ie, with the decimal point between the second and third digits rather than third and fourth.

This modification is done by clearing a solder shorting 'link' on the board and making another one. These solder 'link' positions are between an exposed track and three small rectangular pads near R4 at lower-right, next to the MKT capacitor. Left-to-right, they are labelled S, B and Q (see the instruction sheet supplied with the meter). You will need to clear the short from track L to pad S, and instead short track L to pad B. That's just for the ammeter; leave the other meter (for voltage) with L and S connected.

If you've installed trimpots VR7 and VR8 on the PCB you can put the meters back into their plastic housings and snap the backs on. Otherwise, leave the backs off as you'll need access to the meter trimpots later.

Connecting cables

The next step is to fit polarised header plugs to the bare ends of the supplied hook-up wires. Trim them all to the same length of around 100mm, then strip the ends and crimp them into the pins which are supplied with the polarised header plugs. This is done by folding the two small metal leaves

Running the supply from a higher voltage

We've had enquiries as to whether it's possible to run this unit from a higher voltage DC supply and the answer is 'yes', with a few small modifications. As stated in the previous articles, old laptop and PC power supplies are quite suitable and will typically supply 12-17V, while a typical 6-cell lead-acid battery is also suitable, giving a supply of 13-14.5V while being charged and 12-13V the rest of the time.

However, if you have a 24V (12-cell) lead-acid battery or battery bank, as used in many trucks, boats, caravans and off-grid power systems, it's not a good idea to connect the bench supply as originally designed. That's because the battery will approach 30V during charge, well above the recommended maximum supply of 24V.

There are a few simple changes which will allow operation up to 40V, although we recommend keeping the supply below 30V to avoid excessive dissipation in REG1 due to the relatively high current drawn by the LED panel meters. These are as follows:

- 1) The nine 10 μ F 25V SMD input bypass capacitors for the switchmode section should be replaced with nine 4.7 μ F 50V capacitors (ie, identical to those used in the output filter bank). You could use 10 μ F 50V capacitors instead, to maintain the same capacitance, but we don't think this is necessary.
- 2) The 100 μ F 25V input bypass capacitor for REG1 should be replaced with a 47 μ F 50V/63V electrolytic capacitor.
- 3) Zener diode ZD2 should be changed to a higher voltage type. The recommended value to use is 39V; however, with the above example (ie, running from a 24V lead-acid battery), 33V would also be an acceptable choice.

While REG1 will run hotter with a higher input voltage, under load the switchmode section will likely run somewhat cooler (due to the lower input current) and it may be able to supply a little more current at higher output voltages than would be available with a regulated 24V DC input.

over the exposed portion of the wire and the larger ones over the insulated section and then squeezing them down hard with needle-nose pliers to hold the wires in place.

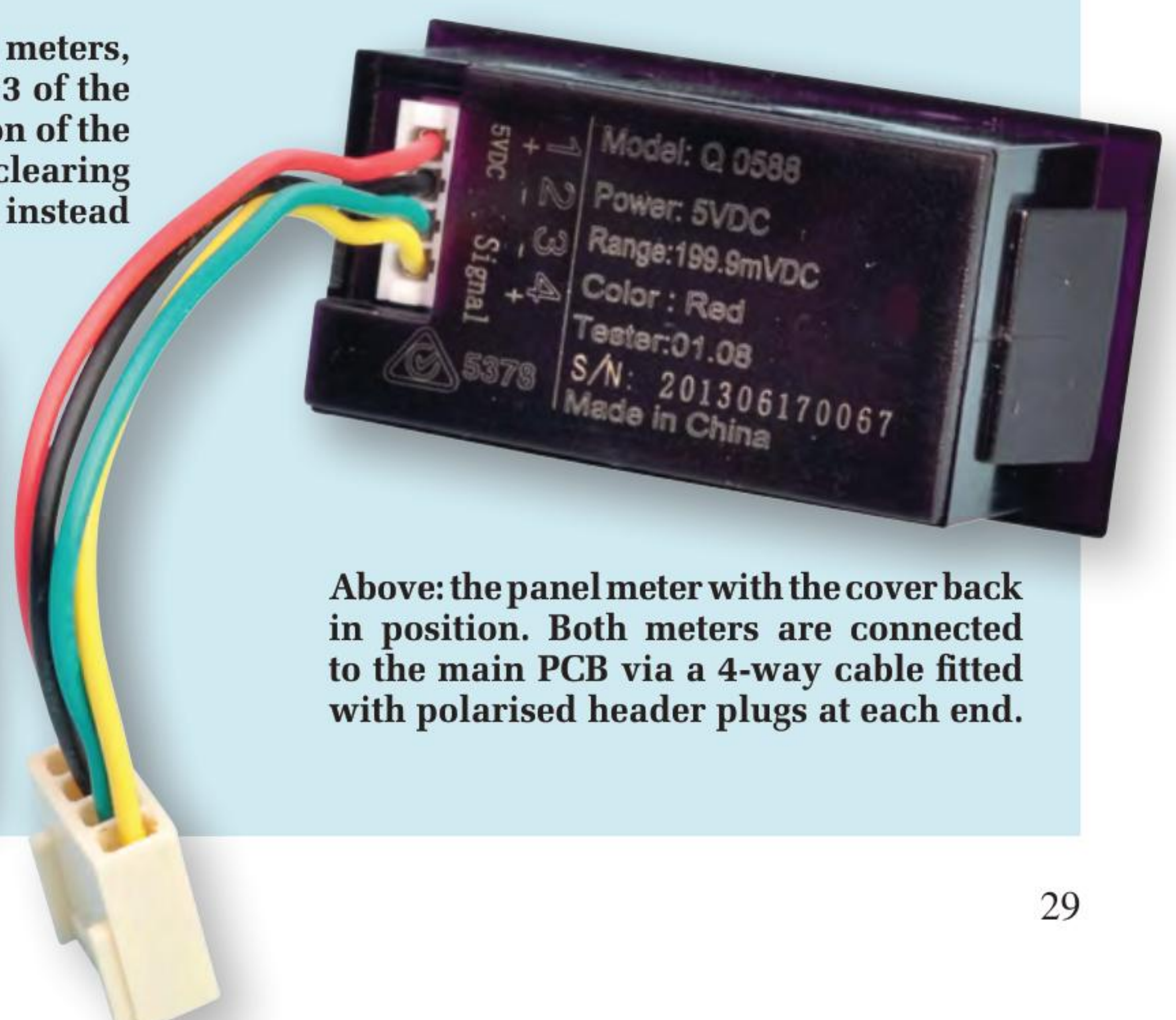
Note that unless you have a specialised crimping tool for this kind of pin, this will be insufficient to retain the wire so you will also need to solder the exposed copper in place. Use only a small amount of solder and don't get

any on the outside of the pin or it won't go into the plastic block.

Once all four wires have pins attached, slide them into the slots in the header block and push them in until they click into place. The wires must be ordered as shown in Fig.7 last month (see photo below).

If you get them wrong, you will have to use a small tool to push gently on the metal flange which retains each

Below: the view inside one of the panel meters. For both meters, you need to remove the short circuit between pins 2 and 3 of the header connector at left. You also need to move the position of the decimal point on one meter (used to indicate current) by clearing the short between track L and pad S at bottom right and instead shorting track L to pad B (see text).



Above: the panel meter with the cover back in position. Both meters are connected to the main PCB via a 4-way cable fitted with polarised header plugs at each end.

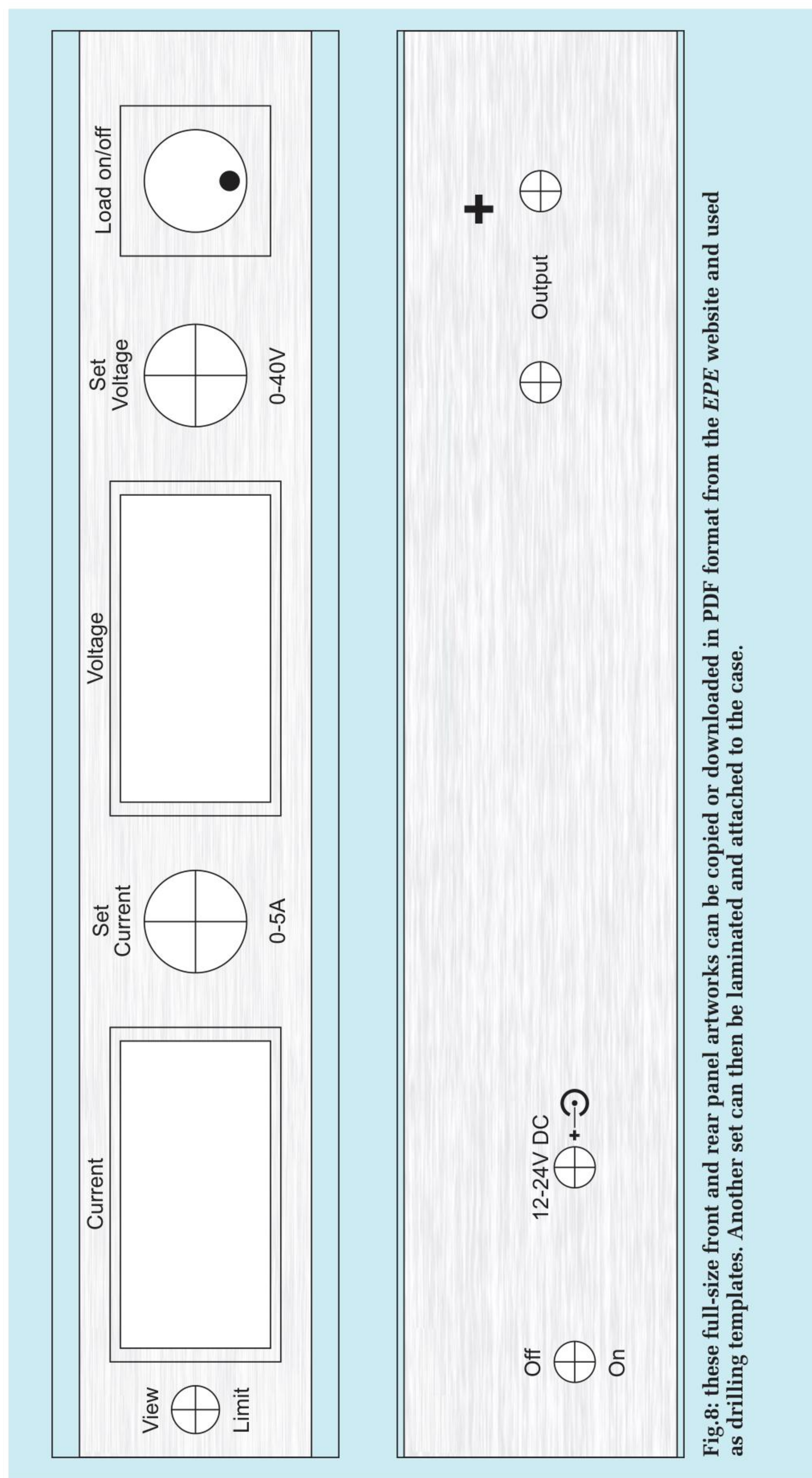


Fig.8: these full-size front and rear panel artworks can be copied or downloaded in PDF format from the *EPE* website and used as drilling templates. Another set can then be laminated and attached to the case.

pin in the block so that you can slide them out.

Connecting VR1 and VR2

VR1 and VR2 need to be connected to the board in order to test it. You can

temporarily fit two 10k Ω 9mm linear potentiometers if you have these on hand; there are pads to do so and this is quite convenient but expensive if you have to purchase them. The alternative is to wire up the chassis-mount pots

you intend to use with the unit and use them off-board.

The 10-turn types generally have three solder lugs arranged front-to-back, with the two on the pot body being the ends of the track and the one at the rear the wiper. However, this isn't necessarily a standard so you really do need to measure the resistance between the terminals to determine which is which. Basically, with the pot fully anti-clockwise, there should be minimum resistance between the left-most and centre pins on CON5 and CON6.

The most convenient way to wire the pots up is to get cables with 3-way female headers on the end, chop them in half and solder the bare ends to the pot. However, this does mean that the plugs can go into CON5 and CON6 either way around, so it would be easy to accidentally reverse the action of one or both pots.

A better but more laborious approach is to make up cables using ribbon cable or light-duty hookup wire with a polarised plug on the end, as described above for the panel meters, but with three wires this time.

Initial checks

Having wired up VR1 and VR2, turn them both full anti-clockwise. Fit LK2 but leave the shorting block off LK1 entirely. With S1 off (up), connect a 12-24V power supply to CON1 and measure the current drain. You can do this by leaving F1 out and connecting a DMM in amps mode across the two fuse clips. There may be a small pulse of current when power is first applied but this should quickly drop to just a few microamps after a second or so; ie, the DMM should read zero unless set on a low-current range.

Assuming that's OK, switch on S1 and check the new current reading. It should be just under 100mA. If it's over 200mA or unstable, switch off and check for faults (eg, incorrectly oriented parts or bad solder joints).

If the current reading is acceptable, you can then check some voltages. The mounting screws of Q1, REG1 and REG2 make convenient ground points (ie, for the black probe).

These voltages should be as follows: bottom-most pin of REG1 = 11.6V to 12.4V (nominal 12V); top-most pin of REG2 = 4.8V to 5.2V (nominal 5V); either end of the 10 Ω resistor above D5 = approximately -10V; bottom-most



The PCB fits neatly inside the instrument case and is secured using self-tapping screws into integral mounting posts. Be sure to modify the supplied panel meters as described in the text.

pin of REG3 = -4.8V to -5.2V ; left-most lead of the 470Ω resistor below VR4 = -2.5V .

Once you have finished these checks, switch off S1 and disconnect the supply. If any of the voltages were wrong, check the circuitry around the regulators and IC2.

Note that with the power switch on and LK1 out, the output of the switch-mode regulator section will be pulled negative by the boost supply charge pump, but it should be clamped by D16 to a safe level of no lower than -0.3V , to protect IC1.

Assuming all is OK so far, with the power off, fit LK1 in the 'TEST' position, then switch back on. Check the supply current; it should now be stable at around 150mA . Turn VR2 clockwise, perhaps 10% of the way through its rotation, then adjust VR1 and monitor the output voltage (ie, between the -OUT and +OUT terminals).

The output should change as VR1 is rotated and be fairly stable up to the input supply voltage, at which point rotating VR1 further clockwise will have little effect. Note that the supply current will drop somewhat when the output is 'pegged'. If VR1 doesn't seem to do anything, try turning VR2 clockwise a bit, as the current limit has not been trimmed yet.

You can now plug in the panel meters and check that they operate correctly. Start with the volt meter and check that its reading can be adjusted with VR1; note that it won't be accurate though, we have yet to trim it. You may notice REG1 and REG2 getting warm with the panel meter connected as it draws a fair bit of current (around 130mA).

You can also now connect the ammeter and check that you don't have the meters mixed up, ie, it should have two decimal places rather than one. But note that it will only read zero because (a) there is no load and (b) S2 is not connected yet. If you really want to check it out, you can short pins 1 and 3 of the header for S2 and then check that you can adjust it through a range of (roughly) $0\text{--}5\text{A}$ with VR2.

Final tests

Now to finally check that it's all working properly. First, switch off and remove power, then switch LK2 over to the 'RUN' position. Adjust VR1 to minimum and VR2 a little above minimum.

If possible, connect a pair of DMMs or a scope to monitor the voltage across D16 as well as the voltage at the output. You may want to insert the 10A fuse now, if you haven't already. If

Part list errata

In the parts list last month, we specified $8 \times \text{BC547}$ transistors and $12 \times \text{BC557}$ transistors. While these would seem to have a sufficient voltage rating (45V for a 40V supply), due to the boosted voltage rails, some transistors may be damaged during operation at high output voltages. Therefore, we suggest all constructors substitute BC546/BC556 transistors respectively for maximum reliability.

Also, we omitted a 200mm length of 10mm diameter heatshrink tubing.

you have a third DMM to measure the amps, connect it across the fuse clips but make sure it's in amps mode (not milliamps).

Re-apply power with S1 off and then switch on. If possible, check the current drain. Without the panel meters connected it should settle at around 120mA , but with the meters connected it will be closer to 400mA . There should be around 1.2V across D16 (the minimum output of the switch-mode regulator) and close to 0V at the output.

Now slowly turn VR1 clockwise. As before, the output voltage should

Can the supply be used as a battery charger?

In short, 'yes', this supply can be used for charging batteries which use a constant-current/constant-voltage charge cycle. This includes lithium ion (Li-Ion), lithium polymer (Li-Po), lithium iron phosphate (LiFePO_4) and (with some manual input) lead-acid batteries, including sealed/gel cells (SLA) and absorbed glass mat (AGM).

Essentially, all you need to do is set the supply's output voltage to the charge termination voltage for your battery pack, set the current limit as high as you can within the capability of the battery itself, connect the supply's output to the battery terminals and turn the load switch on.

The supply will then attempt to pull the battery's terminal voltage up to the set voltage. If it can't, it will deliver the amount of current you have requested until the voltage rises to the set point, then it will keep it there indefinitely. **Caution should be used with lead-acid batteries since generally the maximum voltage that can be applied permanently is around 13.8V (slightly higher for SLA).**

Higher voltages

Higher voltages can be used with lead-acid batteries for more rapid charging; up to about 14.4V for wet cell and 15V for SLA. But the supply can't be left on permanently; the cells will begin to gas once they reach this voltage and the battery will be damaged if this continues for a long time. Typically, you would switch the supply off once the charge current has dropped to about 10% of the set level, or 30-60 minutes after the maximum voltage has been reached.

While no damage should occur if the supply's input power is interrupted (or switched off) with the battery connected and the load switch on, the supply will draw some current from the battery. Therefore, once the battery has finished charging, turn the load switch off before shutting down the supply entirely.

This current is approximately 8-16mA, depending on battery voltage. This flows from the battery, through Q23's body diode and into the output capacitor bank of the switchmode supply. The linear regulator automatically shuts down when the -5V rail is not present, so relatively little current will flow in this condition. However, it may eventually flatten a battery left connected.

increase but the reading across D16 should also increase at the same time, remaining about 0.7V above the output. You should also now find that you are able to turn the output voltage up above the input supply voltage. But do not turn it up much past 40V; we haven't set the maximum voltage yet and this may be possible.

Of course, in theory, the circuitry should limit the output to a safe level, but it's best not to test your luck.

If you've gotten this far, chances are everything is working properly, but before putting it in the case, it's probably a good idea to do a load test and check that the current limiting operates correctly. For this, you will need to solder a length of tinned copper wire into the '-OUT' terminal (you can re-use this wire later to connect it to the binding post).

Having done that, use clip leads to connect a 5W resistor of say 10-100 Ω between -OUT and +OUT (the easiest way to connect to +OUT at the moment is to clip on to the cathode of D13). Next,

turn VR1 and VR2 fully anti-clockwise and switch the power back on, then advance VR1 clockwise – the current meter should still read (near) zero. You can then rotate VR2 and check that the current flow increases linearly.

Check that the unit is able to supply at least a couple of amps but note that the resistor may get quite hot as you turn the voltage and current up. When you're satisfied it's working properly, switch the power off.

Calibration

The next step is to adjust the trimpots. This includes VR3-VR6 on the main board and either VR7/VR8 (if fitted) or the calibration pots on the panel meters.

First, set the output voltage range. Turn VR1 fully anti-clockwise and VR2 to about halfway. Measure the voltage across the outputs with a DMM and adjust VR4 for 0V. Now turn VR3 anticlockwise, then rotate VR1 fully clockwise and adjust VR3 for 40V.

These controls should not interact, but you can re-check the zero voltage

setting if desired. Now adjust VR1 for a non-zero output voltage (5V say), VR2 fully anti-clockwise and wind VR6 all the way anti-clockwise, then slowly advance VR6 until the output voltage returns to the set voltage.

That done, connect a DMM set to read amps across the output. The current flow should be low (a few milliamps). Turn VR5 fully anti-clockwise and then advance VR2 fully clockwise. Adjust VR5 to get a reading of 5A, then disconnect the multimeter (don't take too long on this step).

To calibrate the voltmeter, set the supply for a 40V output and adjust VR7 or its onboard pot until that is what it reads. For the ammeter, connect a DMM in amps mode across the outputs as before, dial in a couple of amps and then adjust VR8 or the ammeter pot until the readings match.

Case preparation

The case for this project is a 1U half-rack plastic case; Altronics part number H4996. However, Altronics have produced a special variation of this case, which has two rectangular cut-outs on the front panel for a pair of their 3.5-digit Q0588 LED Digital Voltmeters, which are supplied with it. They also supply and install an SPST rocker switch.

The catalog number for this half-rack case with the two panel meters and the mains switch is K3205.

Since the case will be supplied with these parts already installed, all you have to do on the front panel is drill the extra holes for the two pots and current-limit-view pushbutton switch. There are four holes required on the rear panel, for the DC input socket, power switch and output binding posts.

Front and rear panel artwork is provided in Fig.8, and these labels can be attached to the front and back of the case to aid in operation. These diagrams can also be used as a guide for drilling the front panel holes. The front panel hole locations aren't especially critical, but for the sake of neatness, it's best to position them where shown.

The rear panel hole locations do need to be accurate however, as the DC input and switch holes must line up with the components mounted on the PCB. The binding posts holes can be moved if required, but be careful that the internal portion of the posts won't interfere with Q23's heatsink fins. We haven't placed them the usual 19mm

apart for this reason, but depending on how far your binding posts project into the case, you may be able to move them closer together.

Drill each hole with a small pilot drill then enlarge them to size using either a series of larger drills or a tapered reamer. Remove any swarf using a deburring tool or oversize drill bit. If you want to attach labels to the front and rear panels, do so now, after cutting out the matching holes.

Putting it together

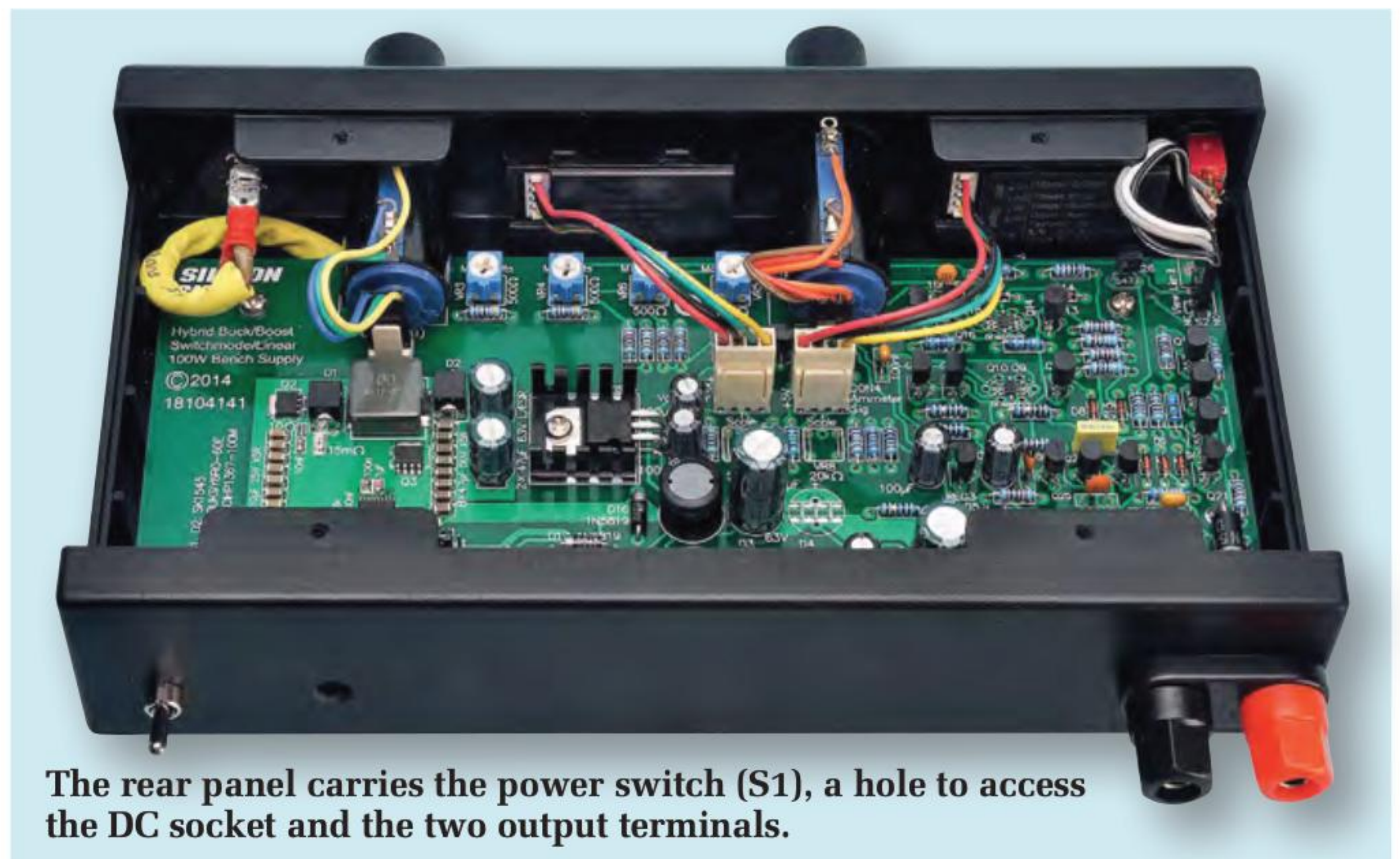
Before proceeding, disassemble the case so that you have four separate pieces – front, back, top and bottom. Don't lose the screws.

Having already soldered leads to the pots, you can now mount them on the front panel and attach the knobs. It's a good idea to terminate the wires with polarised headers so that they can't be plugged in the wrong way around. The wiring diagram (Fig.7) in Part 2 last month showed how our unit was wired, but your pots may have different connections so check these first.

Similarly, solder wires terminated in a 3-pin female header plug to the pushbutton before fitting it to the front panel and pushing the cap on. That done, having prepared the panel meters earlier, pop them back into their plastic housings and clip them into the front panel. Remember that they are configured differently; the meter with track L shorted to pad B (ie, the one you changed) is the ammeter and this goes between VR2 and S2.

There is one more thing to do before putting the board in the case, and that is to make up a cable to connect the output to the load switch. Cut two lengths of extra-heavy-duty hookup wire, 240mm and 260mm long. Strip about 6mm of insulation from each end of both wires and crimp a 6.4mm female spade connector onto one end of each wire.

Now place them side-by-side in a 200mm length of 10mm-diameter heatshrink tubing so that there is about 10mm between the base of each spade connector and the end of the tube, then shrink it down. Solder the free end of the shorter wire to the +OUT terminal on the PCB (near Q23). The other, longer wire can then pass through the adjacent hole and stick out the top of the board by about 30mm. Strip this end back a bit further, leaving around 15mm of bare copper strands.



The rear panel carries the power switch (S1), a hole to access the DC socket and the two output terminals.

Now secure the PCB to the bottom of the case using four No.4 × 6mm self-tapping screws; don't use longer screws or they could damage the case. While doing this, you will need to make sure that the heavy-duty wire runs diagonally under the board to emerge near the opposite corner and that the wires sit side-by-side and avoid any posts or protrusions, otherwise it will be difficult to screw the board down.

Push the crimp connectors onto S1's terminals (either way around), then fit the front panel to the bottom of the case using the self-tapping black screws removed earlier. With that in place you can plug in the two panel meters, the two pots and S2. Pay careful attention to the orientation of any connectors that aren't keyed, especially that for S2.

This requires you to determine the pushbutton switch's common, normally open and normally closed terminals. That's done by setting a DMM on continuity mode and finding the two terminals which are shorted when it is not pressed (COM and NC). You then press the button and the two that are shorted must be COM and NO. You can then plug its connector into the header with the COM, NO and NC connections as shown on the PCB overlay diagram.

Rear panel connections

Now fit the binding posts to the rear panel, making sure their wire entry holes are aligned vertically and that their nuts are done up tight. That done, slip the rear panel over S1 (enlarge the hole if it doesn't fit) and secure it to

the base, **but don't use the supplied screws**; use two black M3 × 5mm machine screws instead. The supplied screws are too long and would interfere with projections from the bottom of the PCB.

Check that a standard DC connector will pass through the remaining hole and mate with the socket on the board; if not, remove the panel and enlarge that hole. You can then wrap the bare ends of the hookup wire attached earlier around the red (+) output binding post and solder it in place.

For the negative output terminal, loop a short section of tinned copper wire around it, solder it in place, then pass this down through the –OUT pad and solder it there. If you need to remove the PCB from the case in future (eg, to troubleshoot it) then you will need to desolder the binding post connections.

Finally, check that the fuse is in place. You can then fire the supply up for a final operational check. It's a good idea to wind the voltage and current knobs down to minimum before powering up and to monitor the input current initially. However, assuming all the earlier tests were OK, as long as the chassis wiring is correct, it should operate correctly.

Check that it works by varying the output voltage and current and perhaps connecting a testing load. It's then just a matter of fitting the lid using the screws you kept from earlier and the supply is complete.

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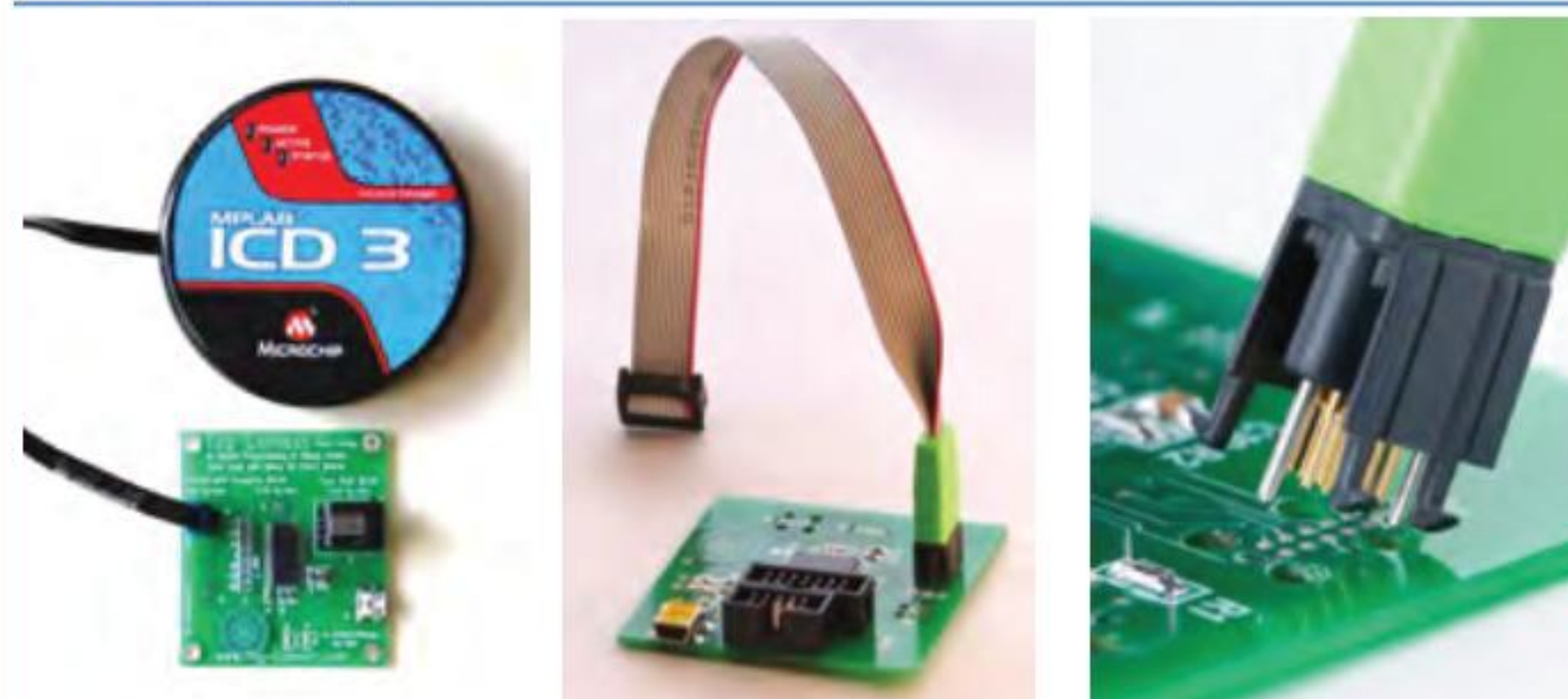


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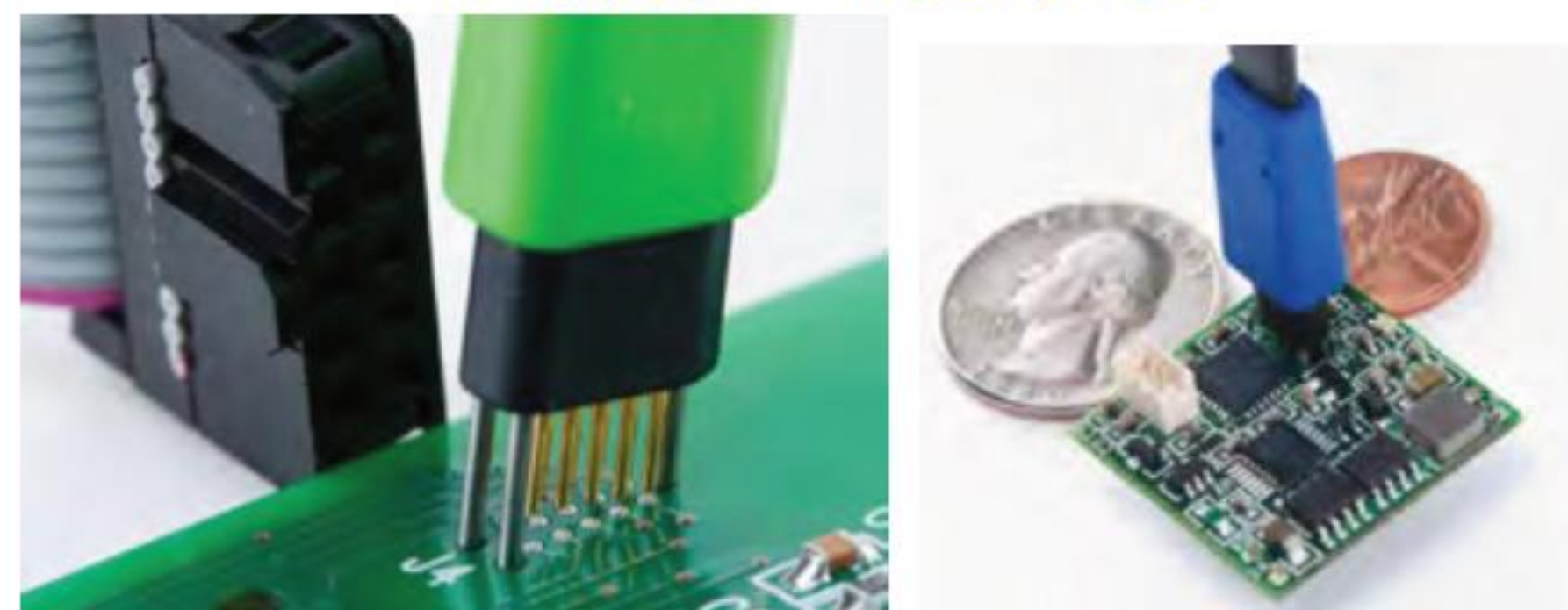
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NET WORK

by Alan Winstanley



Pure madness

ONE OF THE most exciting aspects of dealing with electronics technology is that there is always something new to talk about. The flip side is the high 'churnover' of technology as established favourites are gradually displaced by newer techniques or components. In today's throwaway world the hope is that new tech that one buys into will have a decently long and rewarding life before being consigned to the recycling bin; one reason why the author purchased a Pure Evoke Flow Internet Radio back in 2008.

Pure became a stylish DAB radio marque that started life as the old British VideoLogic brand. The Pure Evoke Flow portable receiver was at the forefront of an emerging trend for radios offering Internet connectivity. Apart from DAB and FM, it could hook to Wi-Fi and pull in myriad IP-based radio stations broadcasting from all over the web. Internet-awareness meant that the 'tuning scale' of Pure's Evoke Flow radio could be pre-configured via the Pure website, where personal favourites could be organised into labelled folders, and the user's radio would seamlessly tune in with the turn of a knob or the flourish of a wireless remote control. Two further bonuses were streaming music over a LAN from a local PC, and streaming MP3 music from a Diskstation NAS.

Equally valuable features have been Listen Again or 'catch-up' radio programs and Pure Sounds, streaming soundscapes such as babbling brooks or rainfall which, coupled with the radio's sleep timer, were a tremendous help in overcoming insomnia. An expensive rechargeable battery made the radio properly portable, and an equally expensive matching extension speaker gave reasonable stereo performance. Overall, the Evoke Flow has been a fine radio and Pure did a good job early on in providing OTA updates that added new functions like dual alarms and energy-saving features. In its heyday, a paid-for music service was trialled that could 'tag' music and let you buy the track on subscription – but, faced with the likes of Amazon Digital Music or Google Play Music it was always a tough sell, and Pure Music was discontinued. Sadly, this was a sign of things to come.

Built-in obsolescence

Today, the radio receiver works as well as ever, except for the fact that Pure has been quietly dropping key functions from the original feature-set of the Pure Evoke Flow. It is no longer possible to configure the aforementioned favourites through a website; it's also impossible to remove legacy music folder 'labels' from the tuner setup which has jumbled up the 'radio dial'. It no longer plays 'Listen Again' programmes from BBC Radio either, this time due to the streaming technology changes made by the BBC itself. Favourites are now handled by an app, and while it does allow 'catch-up' programmes to be added to the radio's menu, they no longer play on this receiver anyway. More recently, the indispensable Pure Sounds service was dropped (end of July) for 'reasons beyond its control'. For the author, this hateful decision is the last straw: with so much promise, all that's left is a DAB clock-radio with clunky IP radio reception and I'm grateful that it still works at all.



The Goodmans Heritage Connect tabletop radio links with Spotify Connect and has Bluetooth, NFC touch-tap and Wi-Fi multi-room audio in a walnut-finish wooden cabinet.

As home networking products continue to evolve, wireless audio streaming has become an everyday function and the Pure Evoke radio range currently includes the Evoke F4, which offers USB and Bluetooth, or the cheaper Evoke F3, which can reach out to play music via a Spotify (online music) account. If I want to nod off to the blissful sounds of rainfall or babbling brooks again, I would need both a new radio and a Spotify account, which offers a limited range of soundscapes. In fact, Spotify Premium costs as much as a new radio does, at £119.98 a year for an uninterrupted ad-free stream. The slashing of useful services that excellent hardware depends on hardly inspires on-going confidence in the brand, especially when Pure is currently being dumped by its owner, Imagination Technologies (<https://imgtec.com>), the loss-making chip maker that counts Apple as a major customer. Imagination claims it's business as usual at Pure – originally built as a showcase for their licensable technology – but Imagination expects to complete the sell-off by the end of 2016.

For alternative ideas, and with one eye on Christmas, there's the Roberts Stream 93i (<http://tinyurl.com/hc6qpwl>) or the very attractive Goodmans Heritage Portable and Goodmans Heritage II Connect tabletop radio, which has Wi-Fi, Spotify, Bluetooth, NFC and that all-important Internet radio connectivity. Goodmans' appealing range has some fun retro flair and can be browsed at: www.goodmans.co.uk/sound/digital-radios.html

New email address

After more than twenty years of service, it's time to retire the column's email address provided by Demon Internet. Vodafone, the current owners of Demon Internet, is shutting down legacy web and 'free' email services and consequently emails addressed to the author should now be sent to alan@epemag.net.

That's all for this month's *Net Work*. You can contact the author at alan@epemag.net or send comments for possible inclusion in *Readout* to editorial@wimborne.co.uk

Teach-In 2016

Exploring the Arduino

Part 10: Ultrasonic proximity sensing

by Mike and Richard Tooley



Welcome to *Teach-In 2016 – Exploring the Arduino*. This exciting new series has been designed for electronics enthusiasts wanting to get to grips with the immensely popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. So, whether you are considering what to do with your Arduino, or maybe have an idea for a project but don't know how to turn it into reality, our new *Teach-In 2016* series will provide you with a one-stop source of ideas and practical information.

Arduino World: Ultrasonic sensors and ranging modules

Low-cost ultrasonic sensors and ranging modules are widely used as a simple means of detecting the proximity of solid objects over distances of up to about four metres. They can also be used to provide

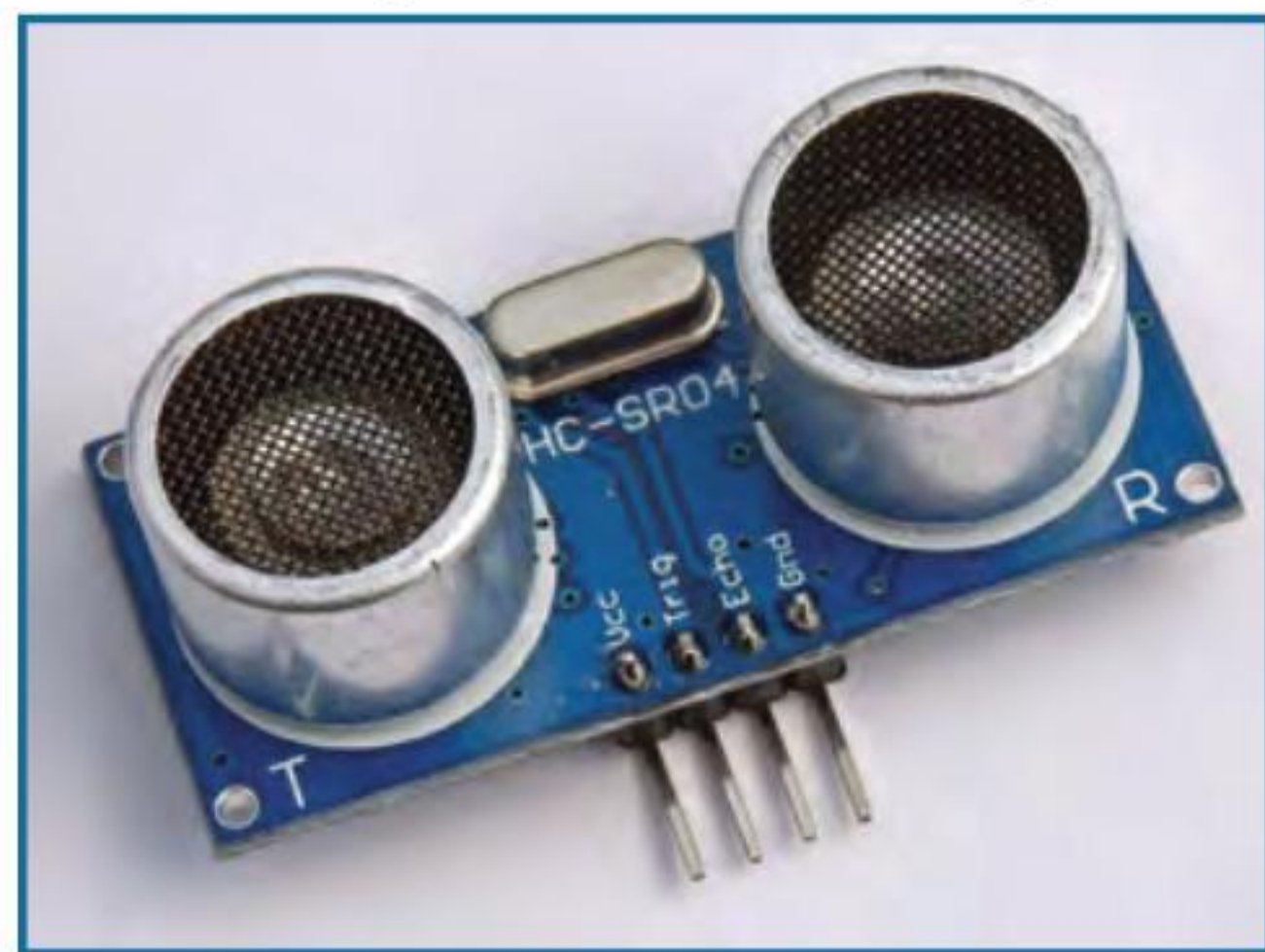


Fig.10.1. Front view of the popular HC-SR04 ultrasonic ranging module

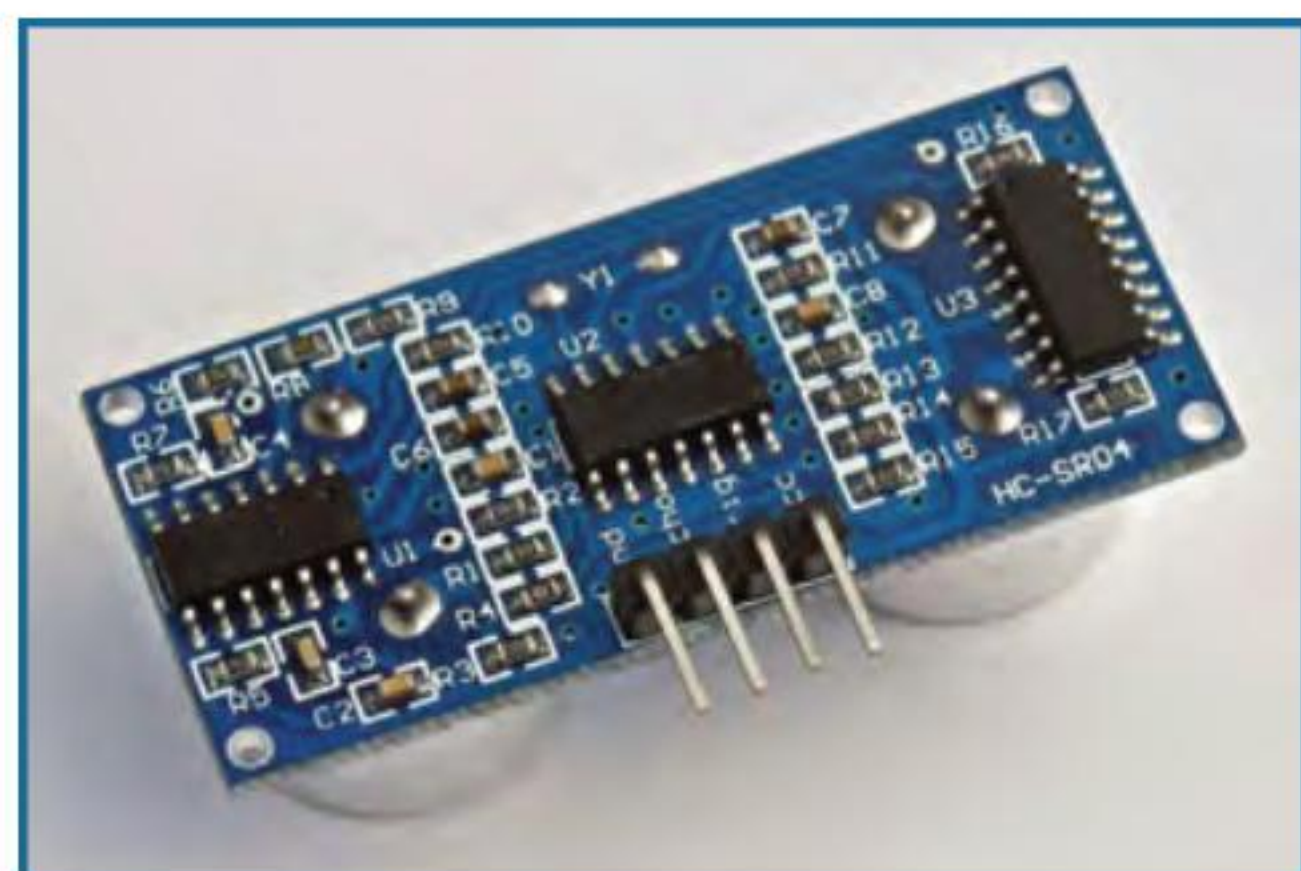


Fig.10.2. Rear view of the HC-SR04 ultrasonic ranging module

Last month, *Teach-In 2016, Arduino World* looked at methods of connecting an Arduino to a local area network (LAN) and to the Internet using an Arduino Ethernet shield. *Arduino Workshop* introduced you to the practical aspects of using Ethernet linking to send and receive data using a standard router or hub fitted with an Ethernet port. Our programming feature, *Coding Quickstart*, introduced the Arduino's comprehensive Ethernet library. Finally, our *Get Real* project features described the design and construction of a highly accurate Internet-connected clock.

a moderately accurate measurement of distance. This makes them suitable for use in a range of applications that involve target detection and distance sensing, such as parking or reversing.

In one of the most popular low-cost ultra-sonic ranging modules, the HC-SR04, an ultrasonic transmitter is paired with an ultrasonic receiver and packaged together with the necessary interfacing logic, allowing it to be connected to the I/O bus of a microcontroller (see Figs. 10.1 and 10.2).

Only four connections are required: +5V, ground, trigger, and echo. In a simple Arduino application, the trigger input to the ranging module is derived from an I/O line configured as an output, while the echo output from the ranging module is connected to an I/O line configured as an input. The pin connections for an HC-SR04 rangefinder module are shown in Fig.10.3 and a brief specifications list is shown in Table 10.1.

Operation

In use, the trigger signal needs to be taken high for a minimum period of 10µs. This results in a transmitted burst comprising of eight cycles of ultrasound at a frequency of 40kHz. If a return signal is detected,

This month

In this issue's *Teach-In 2016, Arduino World* we will examine the use and interfacing of ultrasonic sensors. *Arduino Workshop* introduces you to the practical aspects of object proximity and distance sensing. Our programming feature, *Coding Quickstart* introduces the 'NewPing' ultrasonic rangefinder library and our *Get Real* project describes the design and construction of a proximity warning system based on the Arduino and a low-cost ultrasonic transmitter/receiver module.

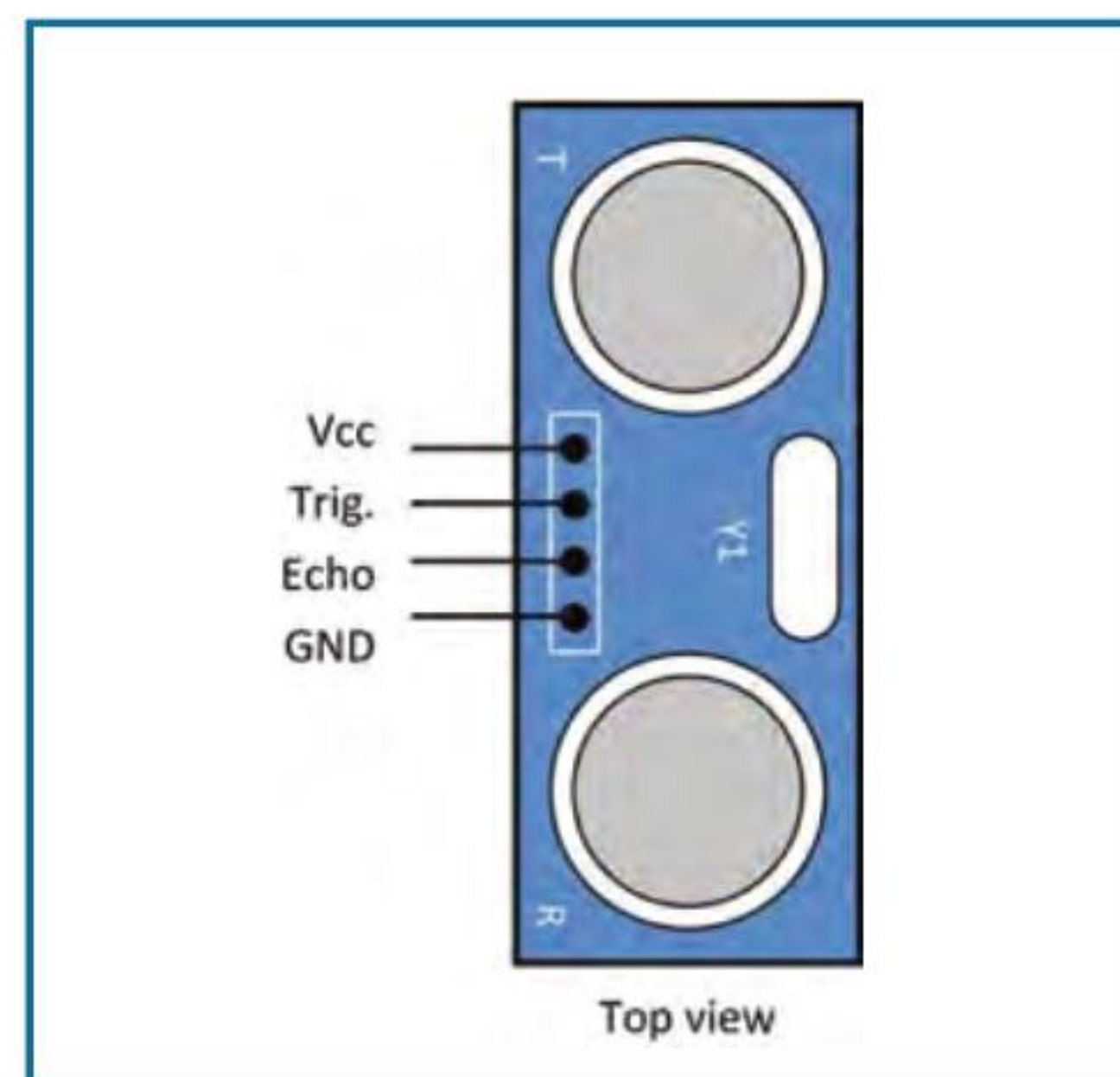


Fig.10.3. Pin connections for the HC-SR04 ultrasonic ranging module

the elapsed time (between the sent burst and received burst) is indicated by the time for which the echo output goes high (see Fig.10.4).

Table 10.1 HC-SR04 rangefinder

Parameter	Specification
Supply voltage	+5V DC
Supply current	< 2mA quiescent; 15mA typical operating
Effective angle	±15°
Effective distance	2cm to 4m (approx. 1 inch to 13 feet)
Trigger pulse width	10µs (TTL compatible)
Dimensions	45mm × 20mm × 15mm

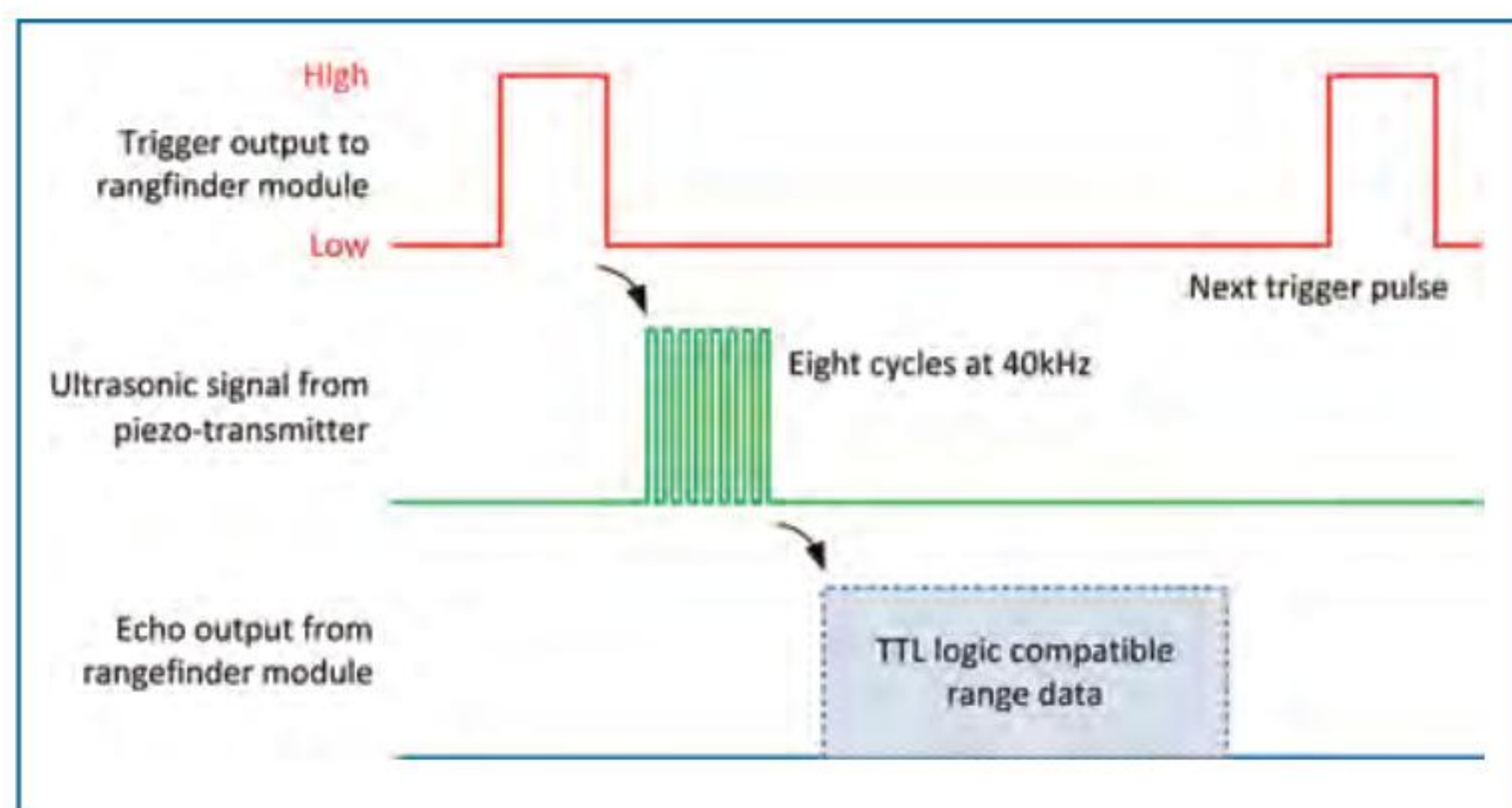


Fig.10.4. Timing of an HC-SR04 ultrasonic ranging module

Arduino Workshop: Using rangefinder modules

In order to determine the distance of a target object from an ultrasonic rangefinder module we need to know the time taken for the ultrasonic pulse to travel to the target and return back to the sensor. We also need to know the speed at which the pulse travels (ie, the speed of sound). This allows us to compute the target distance. A microcontroller such as an Arduino Uno or Nano is able to perform the necessary calculations quickly and easily. Let's take a look at the simple mathematics involved.

The distance from the ultrasonic ranging module to a solid object target is determined from the relationship:

$$d = \frac{1}{2}(t \times v)$$

Where d is the distance in metres (m), t is the width of the echo pulse in seconds (s), and v is the speed of sound expressed in m/s. Now, since v is approximately 340m/s at sea level in dry air at 15°C, we can simplify the expression to:

$$d = 170 \times t$$

So, for example, if the echo pulse goes high for a time of 1.2ms, the distance to the target would be:

$$d = 170 \times 0.0012 = 0.204\text{m} = 20.4\text{cm}$$

Table 10.2 Variation of speed of sound with air temperature at sea level

Air temp (°C)	Speed of sound (m/s)
35	352
30	349
25	346
20	343
15	340
10	337
5	334
0	331
-5	328
-10	325

It can be more convenient to express the duration in microseconds (µs) instead of seconds and the distance in cm rather than m. In this case, the relationship becomes:

$$d = 0.017 \times t$$

It is worth noting that the speed of sound varies with air temperature and altitude. To illustrate this variation, Table 10.2 shows how the speed of sound varies over the temperature range from -10°C to +35°C at sea level.

Designing the code

Now that we are able to calculate the distance using the time taken for the transmitted ping to arrive back at the rangefinder module, we can put together some simple code that will:

- 1) Initialise the hardware by defining the input and output pins
- 2) Send a trigger pulse to the rangefinder module which will then generate an ultrasonic ping from the transmitting transducer (marked 'T' in Fig.10.1)
- 3) Detect any echo received by the

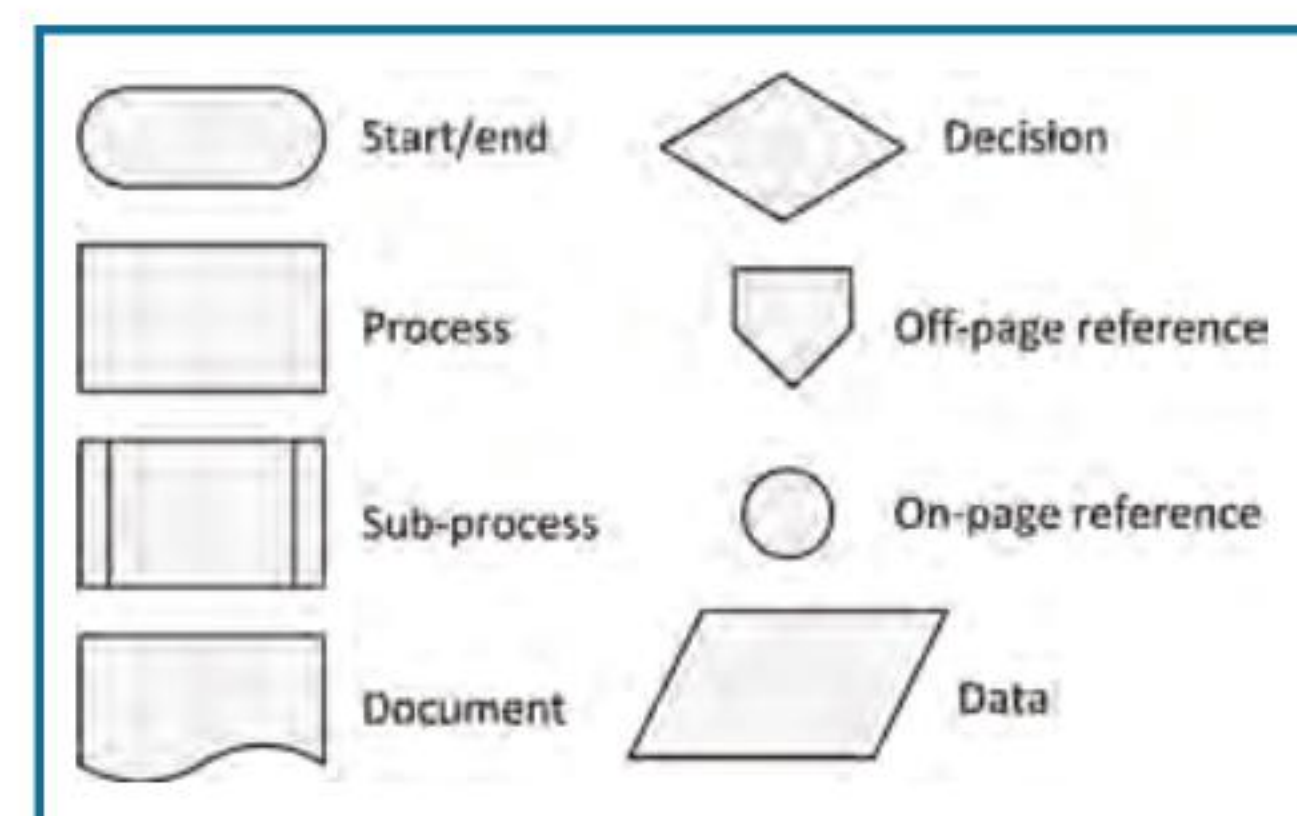


Fig.10.5. Standard flowchart symbols

receiving transducer (marked 'R' in Fig.10.1)

- 4) Calculate the delay between the outgoing and return pulse
- 5) Decide on whether the echo is valid and, if so, convert the delay time to a distance and send the result using the serial monitor
- 6) Send a 'waiting' message via the serial monitor if the echo is invalid
- 7) Repeat steps 2 to 6 indefinitely.

Just in case this is beginning to sound a little complicated there's actually a much better way of describing the code. This uses the standard flowchart symbols shown in Fig.10.5. Our flowchart representation is shown in Fig.10.6.

The code can now be developed along the following lines shown in Listing 10.1. Notice how each of the procedure

Listing 10.1 Simple Arduino-based rangefinder code

```
// Simple rangefinder code
// Requires no library files
int trigger_output = 12; // Trigger output
int echo_input = 11;    // Echo input

long duration, distance;

void setup() {
  Serial.begin (9600);
  pinMode(trigger_output, OUTPUT);
  pinMode(echo_input, INPUT);
}

void loop()
{
  // Generate a clean 10us trigger pulse
  digitalWrite(trigger_output, LOW);
  delayMicroseconds(10);
  digitalWrite(trigger_output, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigger_output, LOW);
  // Detect the echo pulse duration
  pinMode(echo_input, INPUT);
  duration = pulseIn(echo_input, HIGH);
  // Now calculate the distance
  distance = 0.017 * duration;
  // If less than 1m away display the distance
  if (distance < 100) {
    Serial.print(distance);
    Serial.print(" cm");
    Serial.println();
  }
  else {
    Serial.println("Waiting for a target ...");
  }
  delay(250);
}
```

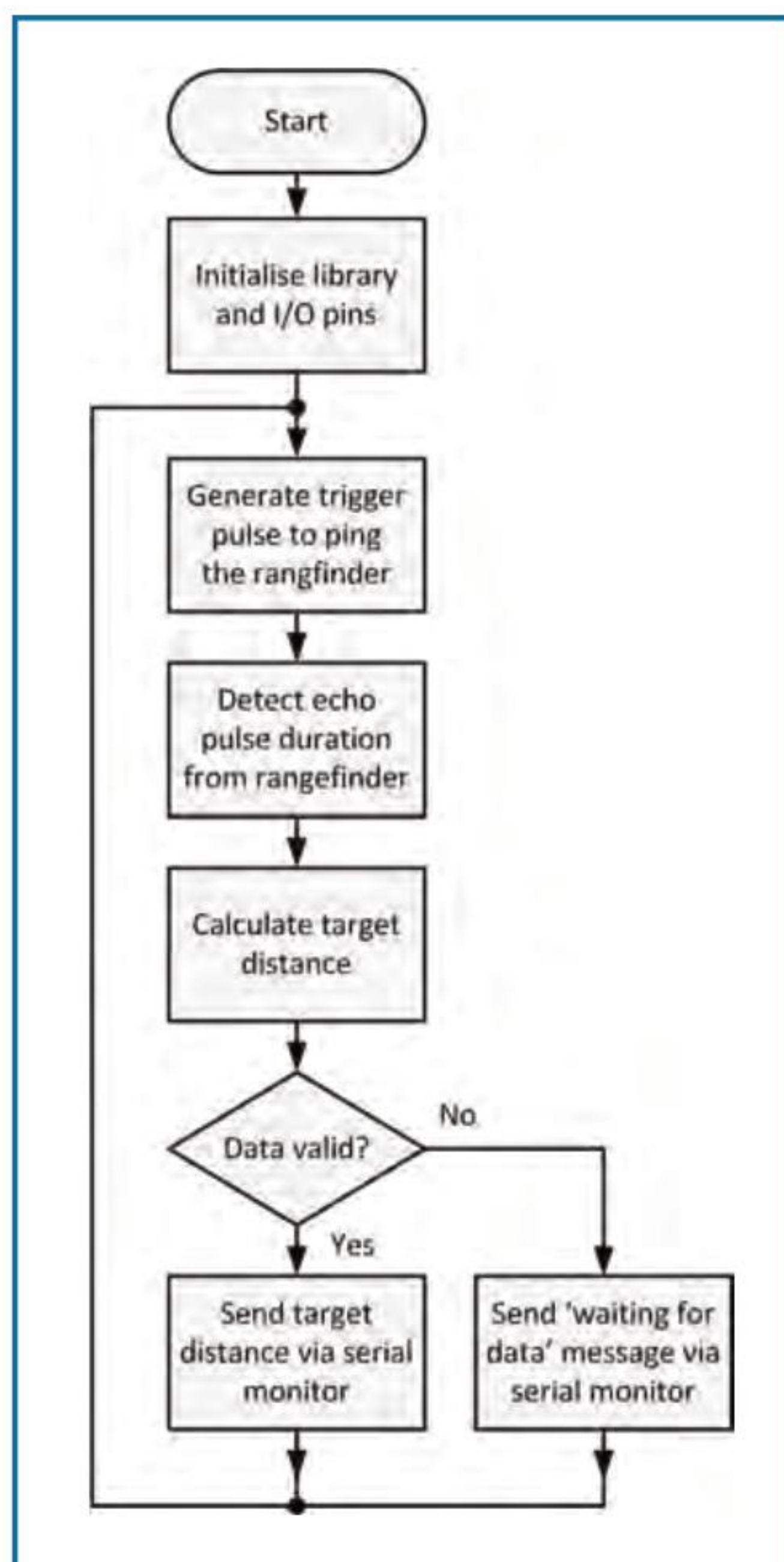



Fig.10.6. Flowchart for the rangefinder application shown in Listing 10.1.

blocks shown in Fig.10.6 corresponds to sections of commented code shown in Listing 10.1. Flowcharts can be extremely useful if you need to develop anything other than the most basic code, and it is well worth getting into the habit of sketching out a flowchart at an early stage, refining it as you build, test and develop your code.

Note that, when working at distance of 1m or more, ultrasonic targets should ideally be solid objects with a flat surface area of around 0.5m². When working at close range (less than about 0.5m) satisfactory results can be obtained with much smaller objects. Note also that, unlike some other types of sensor, operation is unaffected by target orientation and ambient light level. In the case of our simple rangefinder code we've set the maximum target distance of 100cm. Beyond this distance any echo will simply be ignored. We will explain this in a little more detail later.

Coding Quickstart: The NewPing library

The NewPing library developed by Tim Eckel eases the pain associated with developing your own rangefinder code and very neatly handles the conversion of distance to time for both metric and imperial units. The library works with several different types of rangefinder module including the HC SR04, SRF05, SRF06 modules. There is also an

option to interface with all but the SRF06 module using just one Arduino signal pin. The library is able to send and receive (ie, 'ping') consistently and reliably at up to 30 times per second and also incorporates a timer interrupt method for use with event-driven sketches. A built-in digital filter, `ping_median()` is included for quick and efficient error correction. For faster execution and smaller code size, the library code makes use of port registers when accessing pins. In addition, there is the facility to set a maximum distance beyond which pings are ignored and simply treated as a 'no ping' result. The library caters for up to 15 individual rangefinder modules, making it possible to sense over a wide area.

Using NewPing

We first need to initialise the NewPing library by specifying the Arduino pins that we will be using. This involves just one simple line of code of the form: `NewPing sonar(trigger_pin, echo_pin);` – for example:

```
NewPing sonar(12, 11);
```

This initialises the NewPing code so that it uses the Arduino Uno's pin-12 for trigger output and pin-11 for echo input. Since no maximum ping distance has been specified the code will operate with a default maximum ping distance of 0.5m. However, if required, a third

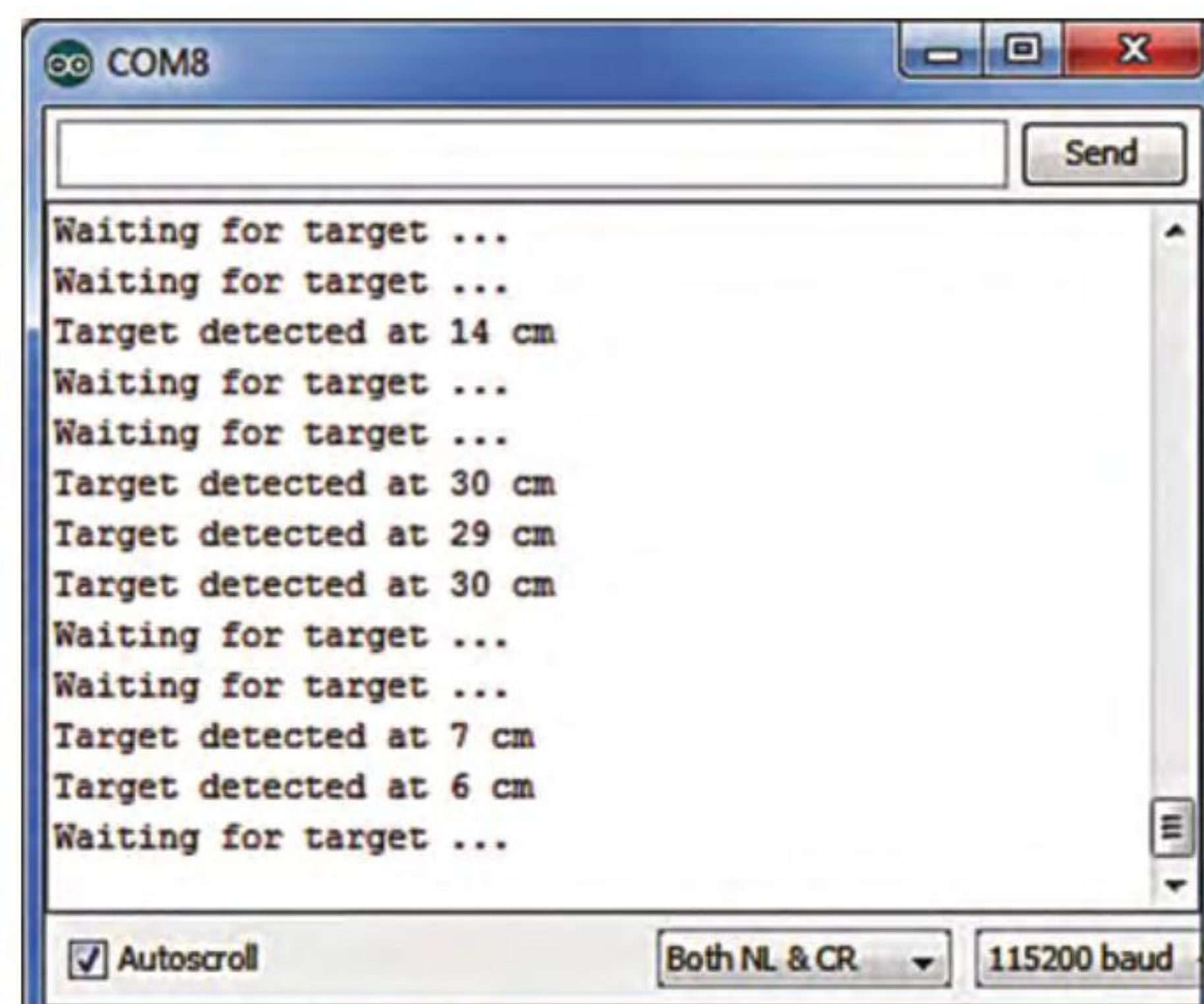


Fig.10.7. Using the Arduino IDE's built-in Serial Monitor to display target distances sensed by an HC-SR04 rangefinder module

parameter can be included in order to specify the maximum ping distance: `NewPing sonar(trigger_pin, echo_pin, max_cm_distance);` – for example:

```
NewPing sonar(10, 9, 250);
```

This initialises NewPing so that the Arduino Uno's pin-10 is used for trigger output with pin-9 for echo input. The maximum ping distance of 250cm has been specified (beyond this distance any received pings will be treated as 'no ping'). The various methods that can be used with the library are summarised in Table 10.3.

Installing the NewPing library

The NewPing library is not currently shipped as part of the Arduino IDE, so you will need to install it using the IDE's

Table 10.3 Methods available for use with the NewPing library

Method	Use
<code>sonar.ping();</code>	Send a ping and return the echo time in microseconds (or 0 if no ping echo is detected within the set distance limit)
<code>sonar.ping_in();</code>	Send a ping and return the echo distance in inches (or 0 if no ping echo is detected within set distance limit)
<code>sonar.ping_cm();</code>	Send a ping and return the echo distance in centimeters (or 0 if no ping echo is detected within set distance limit)
<code>sonar.ping_median(iterations);</code>	Send multiple pings (default = 5), discard out of range pings and return the median time in microseconds
<code>sonar.convert_in(echoTime);</code>	Convert echo time in microseconds to distance in inches
<code>sonar.convert_cm(echoTime);</code>	Convert echo time in microseconds to distance in centimeters
<code>sonar.ping_timer(function);</code>	Send a ping and call function to test if ping is complete
<code>sonar.check_timer();</code>	Check if the ping has returned within the set distance limit
<code>timer_us(frequency, function);</code>	Call the timer function every frequency microseconds
<code>timer_ms(frequency, function);</code>	Call the timer function every frequency milliseconds
<code>timer_stop();</code>	Stop the timer

Listing 10.2 Simple ultrasonic rangefinder for the Arduino Uno

```
// Ultrasonic rangefinder for the Arduino Uno

#include <NewPing.h>          // Include the NewPing library
#define trigger_output 12    // Trigger output to rangefinder module
#define echo_input 11       // Echo input from rangefinder
#define control_input A0     // Threshold control input
#define max_distance 100    // Max. distance to ping (in cm)
long distance;               // Distance of target (in microseconds)

// Parameters required by NewPing
NewPing sonar(trigger_output, echo_input, max_distance);

void setup() {
  Serial.begin(115200);      // Use Serial Monitor to view results
}

void loop() {
  // Set the delay between successive pings
  delay(1000);
  // Generate a ping and calculate the distance
  unsigned int uS = sonar.ping();
  distance = uS / US_ROUNDTRIP_CM;
  // If a valid echo is present compare with threshold setting
  if(uS <<0){
    Serial.print("Target detected at ");
    Serial.print(distance);
    Serial.println(" cm");
  }
  else {
    Serial.println("Waiting for target ...");
  }
}
```

Listing 10.3 Complete code for the Arduino proximity warning system

```
// Simple Arduino Uno proximity alarm with variable threshold
setting

#include <NewPing.h>          // Include the NewPing library
#define alarm_output 13       // Alarm output
#define trigger_output 12    // Trigger output to rangefinder module
#define echo_input 11        // Echo input from rangefinder
#define control_input A0     // Threshold control input
#define max_distance 200    // Max. distance to ping (in cm)
long distance;               // Distance of target (in microseconds)

// Parameters required by NewPing
NewPing sonar(trigger_output, echo_input, max_distance);

void setup() {
  pinMode(alarm_output, OUTPUT); // Set the digital output
}

void loop() {
  // First get threshold value from the control potentiometer
  int rawValue = analogRead(control_input);
  float threshold = map(rawValue, 0, 1023, 0, 200); // Map into range
  // Set the delay between successive pings
  delay(150);
  // Generate a ping and calculate the distance
  unsigned int uS = sonar.ping();
  distance = uS / US_ROUNDTRIP_CM;
  // If a valid echo is present compare with the threshold setting
  if(uS <<0){
    if (distance < threshold) {
      digitalWrite(alarm_output, HIGH); // alarm on
    }
    if (distance >= threshold) {
      digitalWrite(alarm_output, LOW); // alarm off
    }
  }
}
```

Library Manager. First, download the library in a zipped file from **playground.arduino.cc/code/NewPing**. When you have located the NewPing page you can select 'Download NewPing Library' and click on the latest download (currently version 1.8). This will download the zipped file to your computer.

Next, from the Arduino IDE select 'Sketch', 'Include Library' and 'Add .ZIP library', then locate the downloaded zip file and click to 'Open' it. You should now find that NewPing appears in your list of 'Contributed Libraries', allowing you to successfully compile Arduino code that uses the NewPing library.

Using the NewPing library

Listing 10.2 shows just how easy it is to use the NewPing library. Note that in the example we have set the serial bit rate to 115200 bits per second, so you may need to change the Arduino IDE's Serial Monitor bit rate to match this rate (this speed can be set to any of the available values, but the bit rate specified in your code *must* be the same as that selected within the IDE for the Serial Monitor).

Fig.10.7 shows the result of running the code in Listing 10.2. This shows successive targets detected at distances of approximately 7cm, 14cm and 30cm from the rangefinder module.

Get Real: Arduino proximity warning system

In this month's *Get Real* we will be using an Arduino in conjunction with an ultrasonic transceiver module to construct a low-cost proximity warning system. Such a device has a number of applications, including detecting open doors and windows or sensing the proximity of a vehicle to an obstacle such as a wall or another vehicle. The device can also be used to augment a security system, supplementing PIR and other sensors.

You will need

Arduino Uno
HC-SR04 (or similar) ultrasonic rangefinder module
Connecting leads
USB cable with USB connector (for programming only)
Computer with an available powered USB port (for programming only)
Piezoelectric sounder (continuous output type), PZ1
10kΩ linear carbon potentiometer, VR1

Code

The complete code for the Arduino proximity warning system is shown in Listing 10.3. If you have not already done so, make sure that you install the NewPing library as described on the previous page. Note that, for this particular application we've set the maximum target distance to 200cm.

As with our previous *Get Real* projects, the code should first be entered into the IDE and then saved before compiling and uploading it to the Uno as described in last month's *Arduino Workshop*. When you have debugged and corrected your code, don't forget to save it by clicking on 'File' and 'Save' or 'Save As...'. Finally, click on 'Sketch' and 'Verify/Compile'. Any compilation errors will then be reported in the window at the bottom of the IDE.

Testing and adjustment

When you've corrected any coding errors that the compiler reports you will be ready to upload your code to the Uno. Just click on the upload arrow and watch the progress report. After the Uno performs a reset and following a short delay you should hear several beeps from the sounder indicating that the reset has been performed. If you then set the potentiometer (VR1) to maximum sensitivity you should be able to trigger the alarm consistently from distances of up to about 2m. By reducing the setting of VR1 you will be able to set the distance at which the alarm sounds to less than 10cm.

Going further

As always, there's a great deal of scope for going further with this month's *Get Real* project; for example:

- Using multiple rangefinder modules (the NewPing library can cater for up to 15 sensors and some sample code is supplied as part of the library package)
- Using different audible alarms to indicate different target distance (for example, intermittent beeping at distances of between 0.5m and 1m and a continuous tone for distances of less than 0.5m)
- Sending status messages and target distances to a small LCD display.

All of these additions could be easily incorporated into the basic Arduino code and they will provide you with a great opportunity to further develop your coding skills.

Next month

In the next issue, *Teach-In 2016, Arduino World* will look at Global Positioning System (GPS) modules for use with

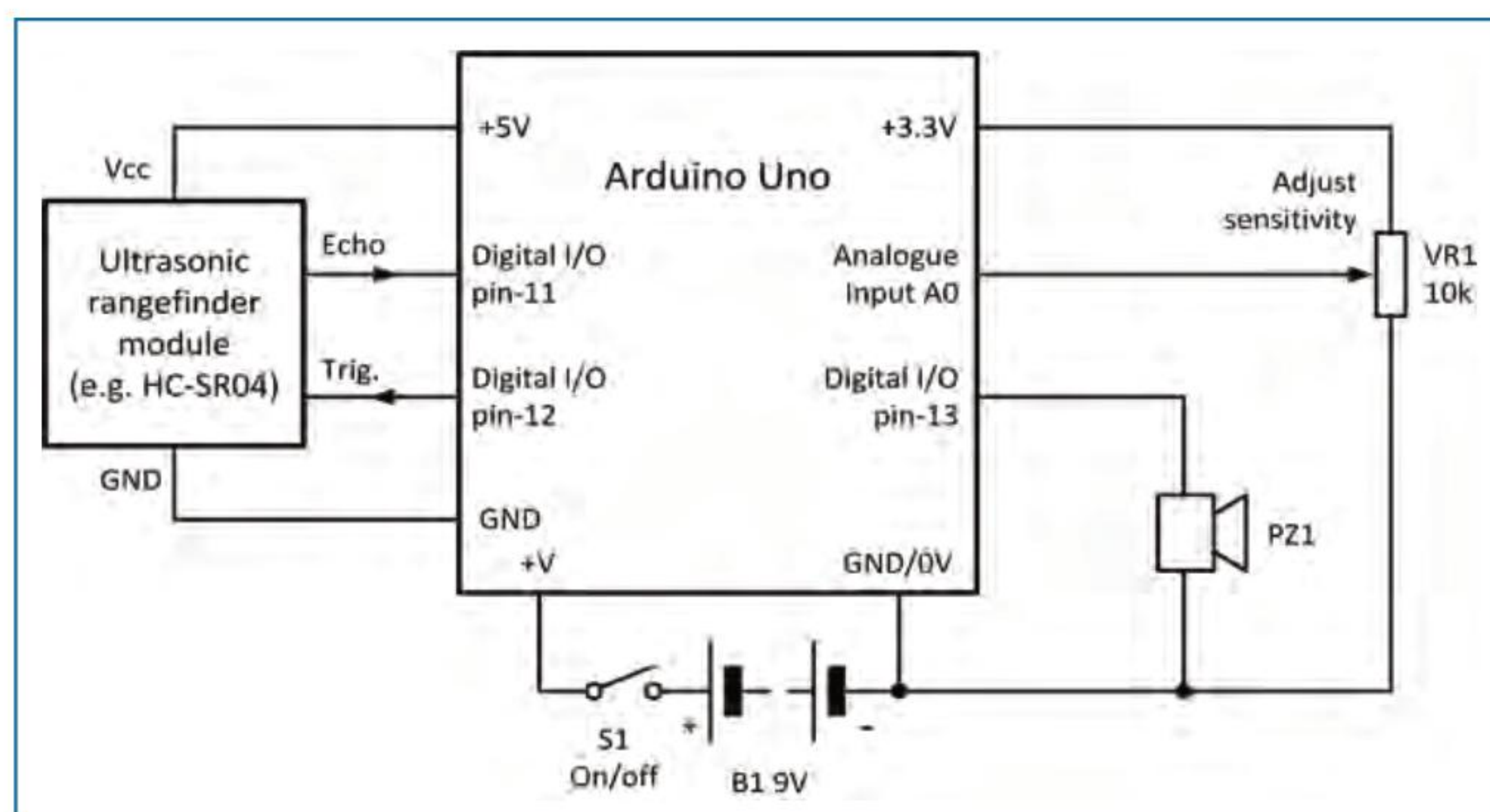


Fig.10.8. Complete circuit of the Arduino-based proximity warning system

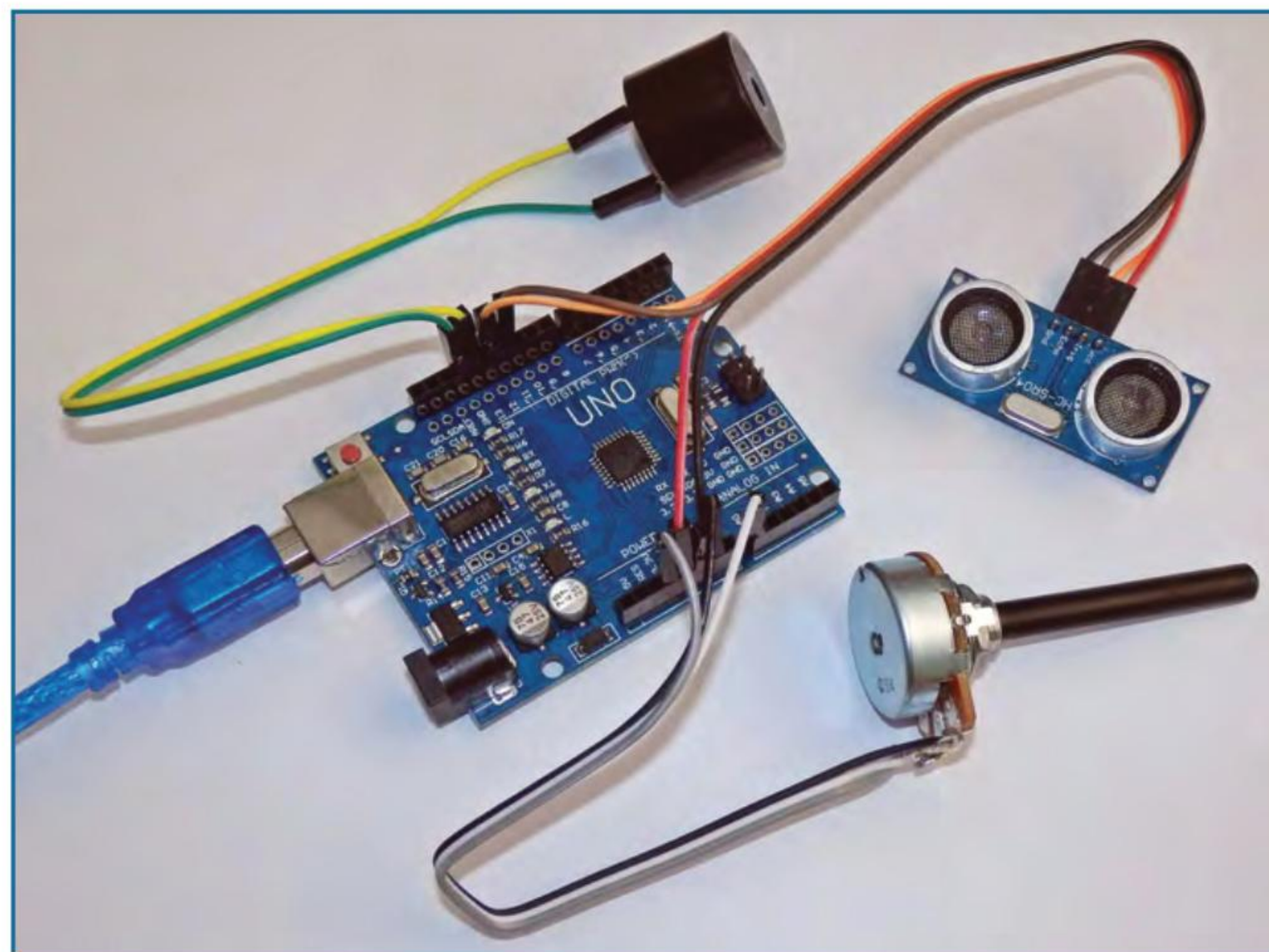


Fig.10.9. The completed Arduino-based proximity warning system

Arduino Beginner?

These YouTube videos were designed to get your project off the ground!

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INTERFACE

Pi millisecond and microsecond timing

SOME RECENT *Interface* articles have been concerned with timing using a Raspberry Pi computer. The built-in facilities are perhaps not all they could be, and are hampered by the computer's use of interrupts. On the face of it, using Python plus a timer module gives a respectable resolution of a millisecond or better. However, in practice, accuracy is hindered by the computer handling interrupts, and results are somewhat jittery. The real resolution is adequate for many purposes, but it does not enable times to be measured to the nearest millisecond.

One way around the problem is to use external hardware to assist accurate time measurement. Unfortunately, there is no clock output on the GPIO port that can be used as the basis of an accurate timing circuit. This was often a feature of home PCs in the 'good old days', and was made easy to implement by their CPU clock generators that often operated at convenient frequencies such as 1MHz, 2MHz or 4MHz. Of course, these days it is quite easy and reasonably cheap to use an external hardware clock generator circuit. With this method, the computer will often provide nothing more than the display and some basic control logic, but this technique offers much better accuracy than can otherwise be obtained. In fact, microsecond-resolution accuracy is easily implemented.

Divide and conquer

The traditional approach to an external clock generator for accurate timing is a crystal-controlled clock

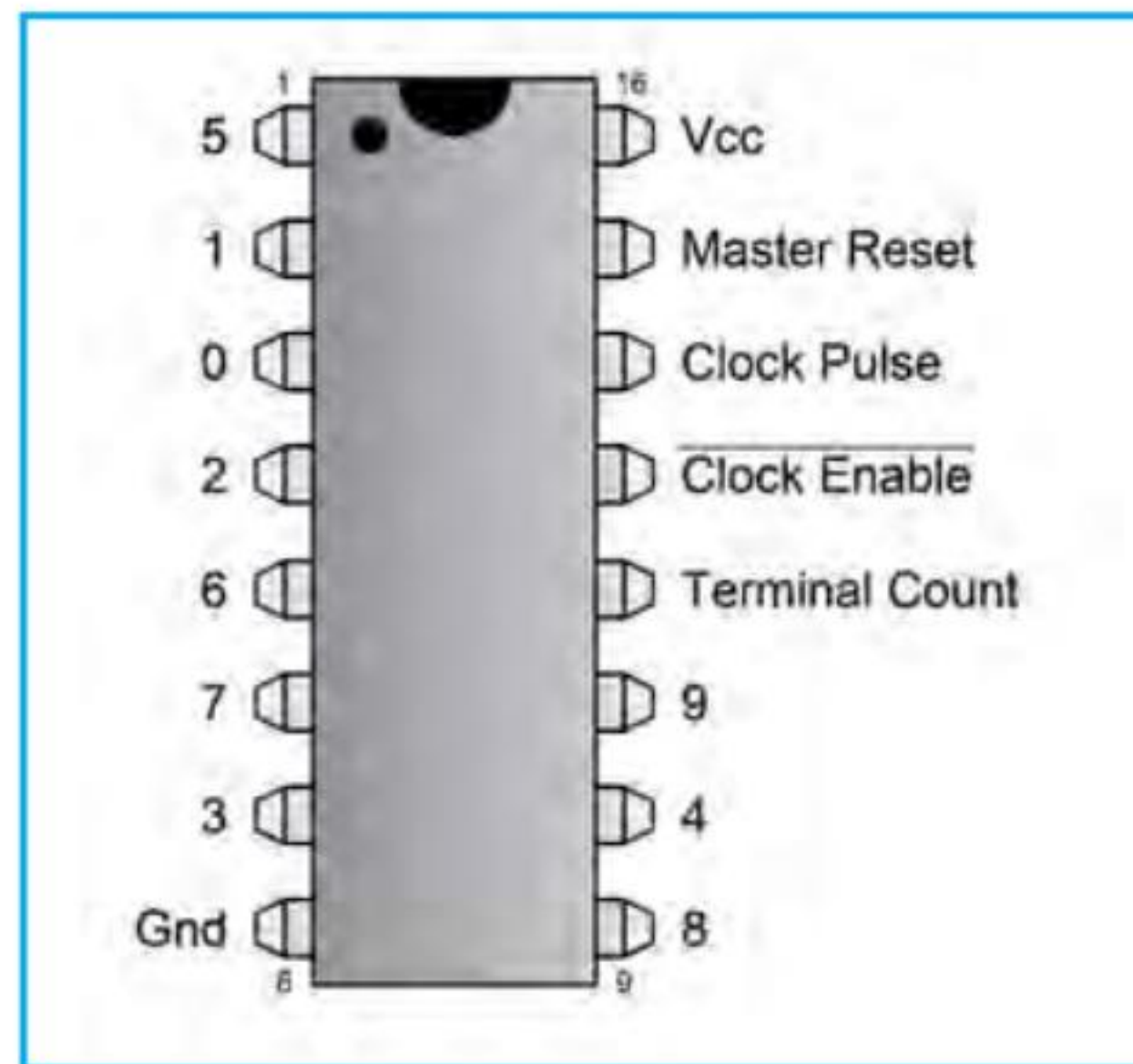


Fig.1. Pin connections for the 74HC4017 decade counter

oscillator and a divider chain. In the current context, the crystal oscillator would operate at a fairly high frequency of several megahertz, and the divider chain would produce lower output frequencies at useful frequencies such as 1MHz, 100kHz, 10kHz... The timing system featured here is based on a 10MHz crystal-controlled oscillator and a series of five divide-by-10 circuits that produce output frequencies from 1MHz to 100Hz.

A series of 74HC4017 chips are used, and Fig.1 shows the pin functions for this device. It has ten outputs ('0' to '9') that go high, in sequence, for one clock cycle. This is a very useful feature that has made the 4017 series of devices popular for use in novelty circuits, and as part of the control logic in more complex circuits. However, in this case it is only the

ordinary Terminal Count output at pin 12 that is required. This is a standard divided-by-10 output that provides a square wave signal.

The output signal can be gated via a control signal applied to the negative Clock Enable input at pin 13, which is taken low to switch on the clock signal. According to some 4017 data sheets, pins 12 and 13 are both clock inputs, and it is possible to apply the clock signal to pin 13. Taking pin 12 high then switches on the clock signal.

Fig.2 shows the circuit diagram for the clock generator circuit. The crystal oscillator is based on Tr1 and Tr2, and it is essentially the same circuit featured in some recent *Interface* articles. IC1 to IC5 provide the series of divider circuits. A gate signal can be applied to the first chip in the divider chain (IC1), and in a normal timing application it is the duration of this pulse that is measured. This input can simply be connected to ground in applications that do not require this feature. There is a reset input at pin 15 of each divider chip, but in this application these inputs are simply connected to ground so that the dividers can run freely.

When used with a Raspberry Pi the circuit is powered from the 3.3V supply available from the GPIO port. This gives compatibility with the GPIO port's input/output lines. Where appropriate, the circuit will work equally well from a 5V supply. Due to the low supply voltage and relatively high crystal frequency, IC1 must be a

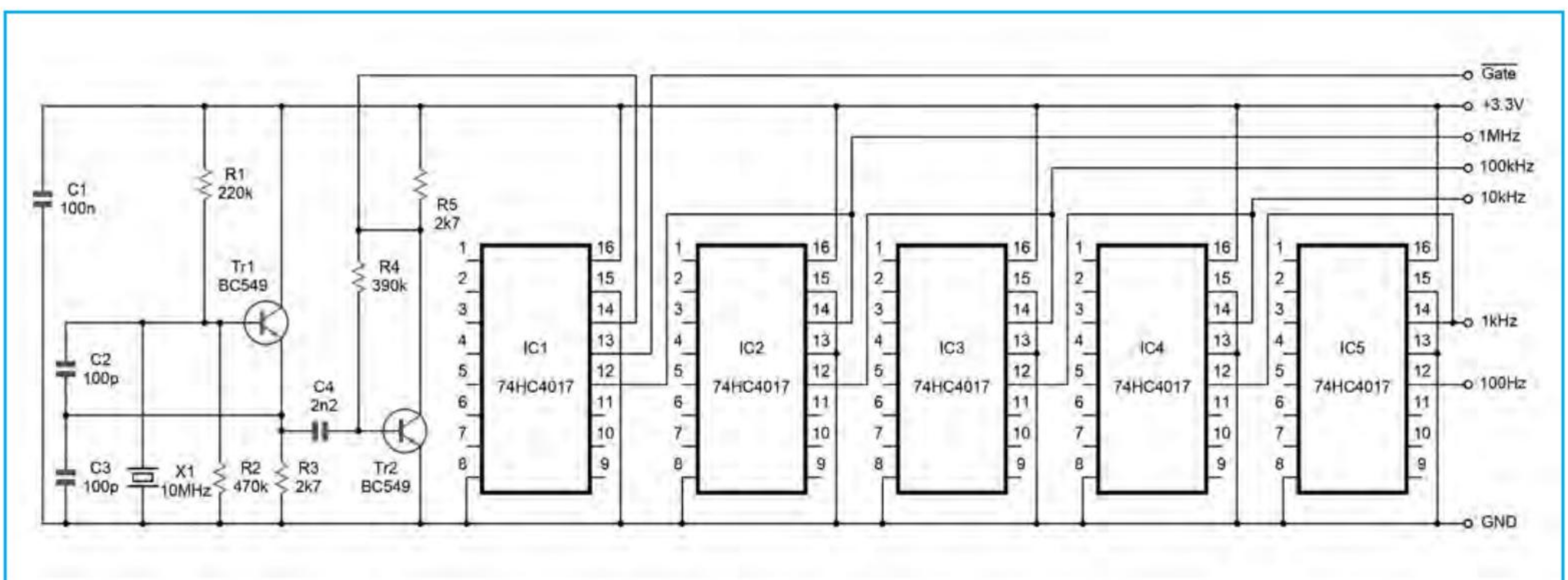


Fig.2. Clock generator circuit using a chain of 74HC4017 decade counters

high-speed CMOS version of the 4017. I used high-speed versions for all five chips, but ordinary 4017s should suffice for IC2 to IC5. Of course, fewer divider circuits can be used if the lower frequency outputs are not needed, or more can be added if lower clock frequencies such as 10Hz and 1Hz are required. All versions of the 4017 are based on CMOS technology and therefore require the usual anti-static handling precautions.

Count on it

The simplest way of using the clock generator is to feed one of its outputs to an input of the GPIO port and then use software to count the input pulses. An obvious drawback of this approach is that it is vulnerable to the same problems as the built-in timing facilities. However, a 100Hz clock signal places only very modest demands on the computer, and this method worked well using the simple Python program of Listing 1. This sets up pins 11 and 19 of the GPIO port as inputs, and they respectively monitor the gate signal and the 100Hz clock signal at pin 12 of IC5.

The first while... loop simply prints 'waiting' on the screen until the gate signal goes to the active state (low). The program then moves to another while... loop that counts the input pulses until the gate signal returns to the high state. The counting is accomplished using three if statements. Initially, none of these will have any effect, but the first one is activated on the first high-to-low transition from the clock generator. The variable called *overflow*, which stores the count, is then incremented by one. The next if statement ensures that the count is not continuously incremented while the clock signal is high. Things are returned to the original state once again by the third if statement when the clock signal does go high again. The first if statement then increments *overflow* by one again, and so on until the gate signal ends. The value in *overflow* is then divided by 100 to give a reading in seconds that is printed on the screen.

Results in practice seem to be excellent, with no pulses missed. In fact, this method seems to work well using the 1kHz clock signal to provide millisecond resolution, but it is unlikely to give accurate results using higher clock frequencies.

Listing 1

```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)

GPIO.setup(11, GPIO.IN)
GPIO.setup(19, GPIO.IN)

overflow = 0
transit = 0

while GPIO.input(11) == GPIO.HIGH:
    print ("waiting")
while GPIO.input(11) == GPIO.LOW:
    if GPIO.input(19) == GPIO.HIGH and transit == 0:
        overflow = overflow + 1
        transit = 1
    if GPIO.input(19) == GPIO.LOW and transit == 1:
        transit = 2
    if GPIO.input(19) == GPIO.HIGH and transit == 2:
        transit = 0

print (overflow/100, " Seconds")

GPIO.cleanup()
print ("Finished")
```

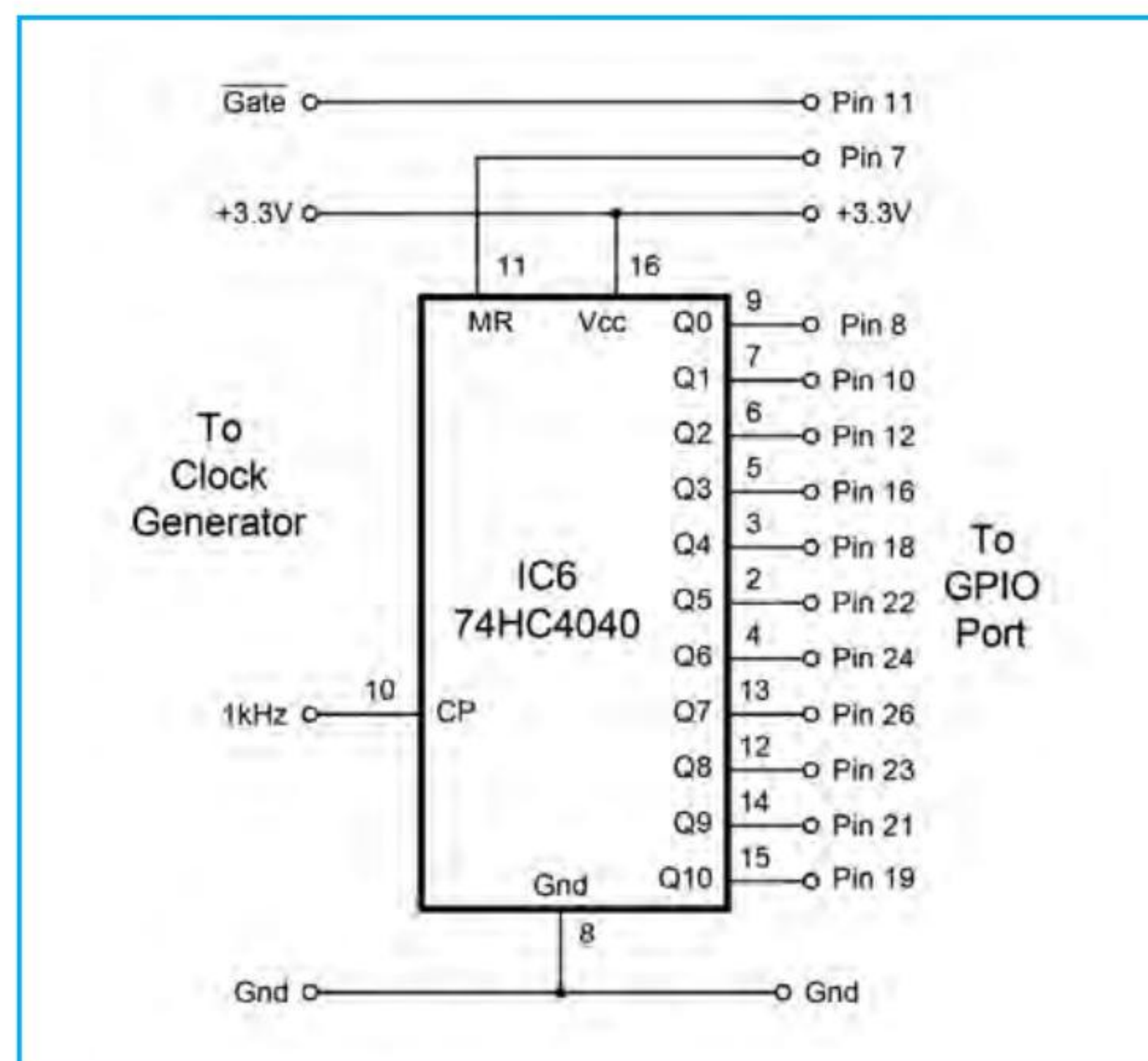


Fig.3. Add-on 11-bit counter to provide hardware-only counting in conjunction with the clock generator of Fig.2

Hardware counter

It is possible to totally avoid any computer-related speed problems by using a hardware counter rather than relying on pulse counting by the computer. The circuit diagram of Fig.3 shows an add-on 11-bit counter that provides this facility in conjunction with the clock generator of Fig.2. This is the same as the counter featured in some recent *Interface* articles, and it will not be considered in detail again here.

Listing 2 is a Python program for use with the counter. After the initial setting up, a reset pulse for the counter is generated on pin 7 of the GPIO port. As before, it prints 'waiting' on the screen until an active gate signal is received, but it then does nothing more than print 'started' until the gate pulse goes high again. The counter is then read bit-by-bit and the total value in milliseconds is printed on the screen. It has been assumed here that

the 1kHz clock signal will be used, and that the value in the counter will be the gate time in milliseconds. Of course, any of the clock generator's outputs can be used, and using the 1MHz output for example, would give a reading in microseconds.

Longer times

Although it provides a high degree of precision, this method has a major drawback in that only short times can be accommodated. The maximum time is just over two seconds using a 1kHz clock signal, and a mere two milliseconds or so with a 1MHz clock frequency! This is adequate for some applications, such as a shutter timer for 35mm film SLR cameras. A 1kHz clock rate could be used for measuring the longer times, with higher clock rates being used for the faster shutter speeds. This would accommodate the longer shutter times while retaining good resolution when checking the faster speeds.

Ideally though, the timer should be capable of measuring very long times with high precision. One way of achieving this is to use a combination of software pulse counting and a hardware counter.

Listing 2

```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)

GPIO.setup(11, GPIO.IN)
GPIO.setup(8, GPIO.IN)
GPIO.setup(10, GPIO.IN)
GPIO.setup(12, GPIO.IN)
GPIO.setup(16, GPIO.IN)
GPIO.setup(18, GPIO.IN)
GPIO.setup(22, GPIO.IN)
GPIO.setup(24, GPIO.IN)
GPIO.setup(26, GPIO.IN)
GPIO.setup(23, GPIO.IN)
GPIO.setup(21, GPIO.IN)
GPIO.setup(19, GPIO.IN)
GPIO.setup(7, GPIO.OUT)

GPIO.output(7, False)
GPIO.output(7, True)
GPIO.output(7, False)
byte = 0

while GPIO.input(11) == GPIO.HIGH:
    print ("waiting")
while GPIO.input(11) == GPIO.LOW:
    print ("started")
    if GPIO.input(8):
        byte = byte + 1
    if GPIO.input(10):
        byte = byte + 2
    if GPIO.input(12):
        byte = byte + 4
    if GPIO.input(16):
        byte = byte + 8
    if GPIO.input(18):
        byte = byte + 16
    if GPIO.input(22):
        byte = byte + 32
    if GPIO.input(24):
        byte = byte + 64
    if GPIO.input(26):
        byte = byte + 128
    if GPIO.input(23):
        byte = byte + 256
    if GPIO.input(21):
        byte = byte + 512
    if GPIO.input(19):
        byte = byte + 1024

print (byte, " milliseconds")

GPIO.cleanup()
print ("Finished")
```

The Python program of Listing 3 uses elements of the previous two programs to read the first 10 bits of the counter, and count the overflow pulses from the 11th bit. With a 1kHz clock signal there is only one overflow pulse every two seconds or so, and no real risk of pulses being missed. In fact, things are not too demanding using the 1MHz clock signal, which gives microsecond resolution while still permitting long pulse durations to be measured.

It should be borne in mind that the gate signal must switch cleanly from one state to the other, particularly on the falling edge. Any bounce or other noise could impair accuracy, and in an extreme case would start the count and then halt it almost immediately. Also keep in mind that the speed of the sensor, or other

Listing 3

```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)

GPIO.setup(11, GPIO.IN)
GPIO.setup(8, GPIO.IN)
GPIO.setup(10, GPIO.IN)
GPIO.setup(12, GPIO.IN)
GPIO.setup(16, GPIO.IN)
GPIO.setup(18, GPIO.IN)
GPIO.setup(22, GPIO.IN)
GPIO.setup(24, GPIO.IN)
GPIO.setup(26, GPIO.IN)
GPIO.setup(23, GPIO.IN)
GPIO.setup(21, GPIO.IN)
GPIO.setup(19, GPIO.IN)
GPIO.setup(7, GPIO.OUT)

GPIO.output(7, False)
GPIO.output(7, True)
GPIO.output(7, False)
byte = 0
overflow = 0
transit = 0

while GPIO.input(11) == GPIO.HIGH:
    print ("waiting")
while GPIO.input(11) == GPIO.LOW:
    if GPIO.input(19) == GPIO.HIGH and
transit == 0:
        overflow = overflow + 1
        transit = 1
        if GPIO.input(19) == GPIO.LOW and
transit == 1:
            transit = 2
            if GPIO.input(19) == GPIO.HIGH and
transit == 2:
                transit = 0

    if GPIO.input(8):
        byte = byte + 1
    if GPIO.input(10):
        byte = byte + 2
    if GPIO.input(12):
        byte = byte + 4
    if GPIO.input(16):
        byte = byte + 8
    if GPIO.input(18):
        byte = byte + 16
    if GPIO.input(22):
        byte = byte + 32
    if GPIO.input(24):
        byte = byte + 64
    if GPIO.input(26):
        byte = byte + 128
    if GPIO.input(23):
        byte = byte + 256
    if GPIO.input(21):
        byte = byte + 512

overflow = overflow * 2048
byte = byte + overflow
print (byte, " milliseconds")

GPIO.cleanup()
print ("Finished")
```

circuit generating the gate pulse, is important when using microsecond resolution. Optical sensors for instance, are often relatively slow and these could limit the overall accuracy of the system.

Op amp instability

RECENTLY, user *lost* started a thread on the *EPE Chat Zone* concerning op amp stability. He asked: 'If an op amp runs out of phase margin before the gain is < 1 will the amp oscillate? What determines the frequency of oscillation?'

The discussion in this thread was on-going at the time of writing, but so far it has highlighted the possibility of confusion around terms and concepts related to this issue (such as 'phase margin' and 'loop gain'). So, this month we will look at some of the fundamentals of op amp amplifier circuits and feedback in the context of amplifier stability, define the relevant terms and concepts, and discuss the conditions under which an op amp amplifier may become unstable. The discussion thread also mentions the use of buffer amplifiers used in combination with op amps, we will not cover this now, but it is a possible future topic.

Op amps

Op amps are high-gain, direct-coupled amplifiers. The term direct-coupled means that the op amp's inputs and internal stages are interconnected directly, not via coupling capacitors. This enables op amps to amplify DC and very low frequency signals. The output of an op amp, V_o , without any additional external components is given by:

$$V_o = A_o(V_1 - V_2)$$

Here, V_1 is the voltage on the non-inverting input, V_2 is the voltage on the inverting input (see Fig.1) and A_o is the open-loop voltage gain, which is specified on a device's datasheet and is typically in the range 70 to 150dB (approximately 3000 to 30 million).

The gain equation shows that op amps have *differential* inputs, which means they amplify the difference between two voltages (V_1 and V_2) rather than the voltage between ground and a single input. Of course, not all applications process differential inputs, but, as we'll see later, it is straightforward to create single-input amplifier circuits from an op amp. In the simplest case, just grounding the non-inverting input means the op amp will amplify the voltage at the inverting input with respect to ground. The differential

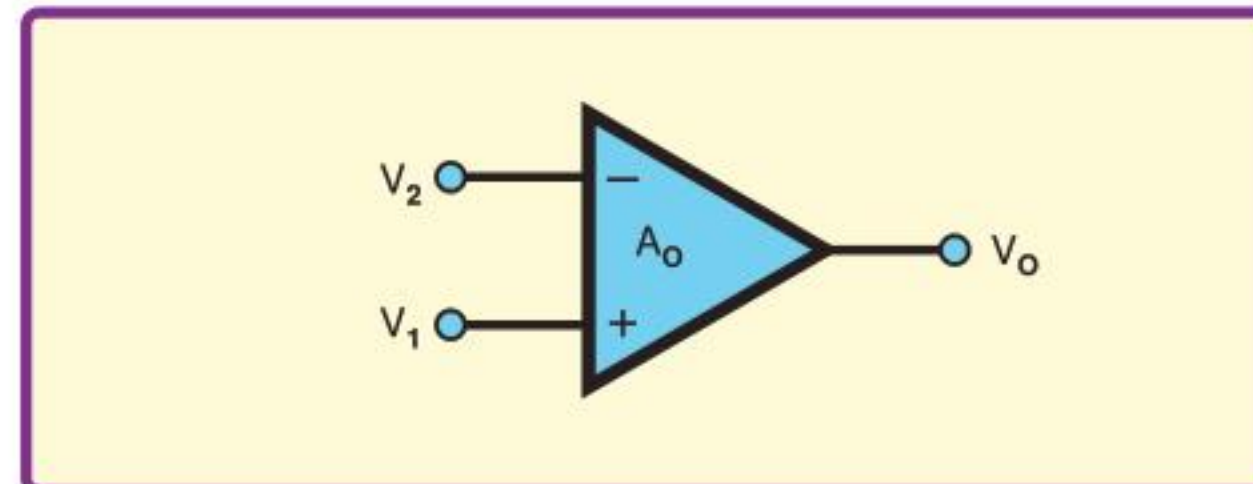


Fig.1. Open-loop op amp

input circuit is there to help deliver high amplifier performance, provide flexibility in performing various circuit operations and facilitates the connection of various feedback configurations, mixing the input with feedback.

Op amps are usually used with *negative* feedback – a fraction of the output signal is fed back and *subtracted* from the input (if the output is added we have the generally much less desirable *positive* feedback). This creates a loop from output back to input and then to the output again – hence the term 'feedback loop'. This is why the gain of the op amp device on its own is referred to as 'open-loop gain', the gain when the feedback loop is open, or not connected.

Governor

The use and occurrence of negative feedback is not limited to electronics – it occurs in nature (in biological systems) and is used in many areas of engineering. Perhaps one of the most often-cited early examples of negative feedback is the centrifugal governor used in steam engines, which was developed by James Watt in 1788, although similar systems predated it. In general, negative feedback is about regulation and control. For example, in the case of the steam engine governor, if the engine is tending to slow down, the negative feedback increases the flow of steam, which causes the engine to speed up (and vice versa). This keeps the speed constant even if the load on the engine varies. This process is limited of course – if a constant speed requires more steam than can be supplied the engine will slow down.

In an op amp amplifier the negative feedback regulates/controls the differential input voltage to the op amp to be zero. The input to the op amp is a function of the circuit input minus the feedback. If the input voltage to the circuit changes then the op amp output changes until the subtraction of the feedback reduces the voltage across the op amp's inputs to zero. Thus the output voltage will track changes in

the circuit's input voltage in a manner determined by the feedback, all the while keeping the voltage across the op amp's inputs zero.

The smaller the fraction of the output that is fed back, the larger the change in output required to compensate for a given input change. Thus, the gain of the circuit depends on the feedback fraction, with smaller proportions of feedback giving higher circuit gain. However, because the gain actually comes from the op amp, the feedback process will only work if the circuit gain (with feedback) is lower than the op amp open-loop gain.

High gain

The gain of the op amp itself does not change when we apply feedback – it is the gain of the whole circuit that is determined by the feedback. In fact, the input-output relationship of the op amp remains exactly as given in the equation above when the feedback is in place. This implies the input voltage difference is actually V_{out}/A_o , not zero as in the preceding discussion. Zero input difference is an ideal case which occurs for an op amp with infinite gain. However, many real op amps do have extremely high gains (hundreds of thousands or even millions) so for outputs of a few volts the input voltages are very small and we have a very close approximation to the description given above.

In an analogy to the centrifugal governor mentioned above, the op amp amplifier can 'run out of steam'. Specifically its output voltage is limited (often to something at, or close to, the power supply voltages). If voltage at the output required to control the op amp's differential voltage to zero is beyond the maximum output range (in either direction) then the feedback process will no longer be controlling the circuit. In amplifier terms we will see clipping of the output signal. Furthermore, the assumption, as discussed above, that the voltage across the op amp's inputs is very small may no longer be true.

The most basic and commonly used op amp amplifier circuits in which negative feedback is applied are the inverting or non-inverting amplifier configurations – see Fig.2. In both cases the negative feedback is applied via a pair of resistors that act as a potential

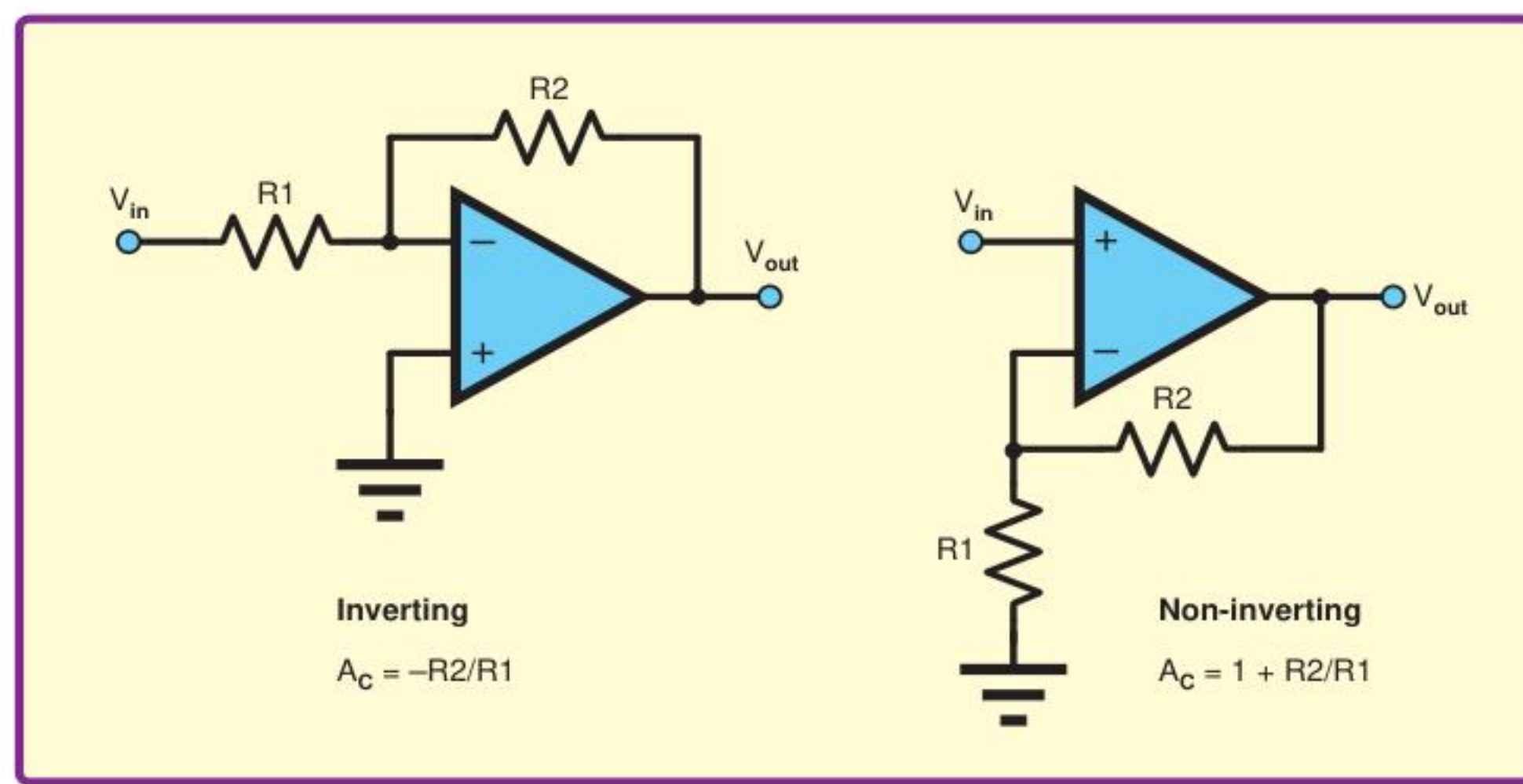


Fig.2. Op amp amplifiers

divider feeding a fraction of the output voltage back to the inverting input. The gain of these circuits is therefore related to the ratio of the resistor values, which sets the proportion of the output fed back by the potential divider. The amplifier as a whole is either inverting (negative gain) or non-inverting (positive gain) depending on whether the input signal is routed to the inverting or non-inverting input.

Structure

An abstract diagram of the structure of an amplifier with feedback is shown in Fig.3 (the amplifier could be an op amp, but does not have to be). The signals, labelled S, could be either voltages or currents. In general, the input signal (S_{inp}) may pass through an input network, as shown, but for our initial discussion, to keep things simple, we will assume this is not present or has no effect (ie, it multiplies the input by one). The input signal passes to the mixing network, which subtracts the feedback (S_f) from the input to produce the signal input to the amplifier: $S_{ai} = S_{inp} - S_f$. The feedback is obtained from the output of the amplifier by passing it through the feedback network, which multiplies it by a factor of β , so $S_f = \beta S_o$. β is known as the 'feedback factor' and is typically less than or equal to one: $\beta \leq 1$.

We have three different gain values that can be used when discussing the amplifier with feedback. These relate to the three paths in the circuit depicted in Fig.4. First, the amplifier on its own has an open-loop gain of $A_o = S_o/S_{ai}$. Secondly the whole circuit (amplifier with feedback) has a closed-loop gain of $A_c = S_o/S_{inp}$. Finally the value $-\beta A_o = S'_f/S_f$ is known as the loop gain. To obtain the gain around the complete feedback loop we create a hypothetical break and find the relationship between signals either side of the break (S'_f and S_f in this case), as shown on Fig.4. Mixing up these gain values, or not being certain which one to use in a given situation, is a possible source of confusion when thinking about circuits with negative feedback.

Calculations

Referring to Fig.3, we can calculate the closed-loop gain in terms of the open-loop gain and feedback factor. The feedback signal is the output multiplied by the feedback fraction (βS_o). Subtracting the feedback signal from the circuit input gives the amplifier input as:

$$S_{ai} = S_{inp} - \beta S_o$$

The amplifier (and circuit) output is the amplifier input multiplied by the amplifier open-loop gain:

$$\begin{aligned} S_o &= A_o S_{ai} \\ S_o &= A_o (S_{inp} - \beta S_o) \\ S_o &= A_o S_{inp} - \beta A_o S_o \end{aligned}$$

Collecting the output terms together gives:

$$\begin{aligned} S_o + \beta A_o S_o &= A_o S_{inp} \\ (1 + \beta A_o) S_o &= A_o S_{inp} \end{aligned}$$

Rearranging to find the closed-loop gain:

$$A_c = \frac{S_o}{S_{inp}} = \frac{A_o}{(1 + \beta A_o)}$$

This is a very important result from which we can show that negative feedback tends to make the gain of the circuit (closed-loop gain) insensitive to variations in amplifier gain (open-loop gain). We will not perform the full sensitivity analysis here, but it turns out that the larger the magnitude of $(1 + \beta A_o)$ the less sensitive the gain of the whole circuit is to the amplifier gain. This lack of sensitivity can be illustrated by a numerical example. If we have an amplifier with a gain $A_o = 100,000$ (easily obtained with an op amp) and use a feedback factor of $\beta = 0.1$, the above equation gives the closed-loop gain as 9.9990. If we double the amplifier gain, keeping $\beta = 0.1$ then the closed-loop gain becomes 9.9995, a shift of just 0.005%.

Improved characteristics

As well as making the circuit less dependent on an individual op amp's characteristics, such as gain, this result means that feedback helps keep the gain of a circuit constant against variations such as temperature and supply voltage, which will affect the op amp open-loop gain much more strongly than the resistor values used to set the feedback. Further analysis can demonstrate that negative feedback can improve other circuit characteristics (for example the effective output impedance of a voltage amplifier can be reduced).

With the values just used we find that the value of $(1 + \beta A_o)$ is completely dominated by βA_o ; that is, the 1 hardly makes any difference. βA_o is 10000, and $(1 + \beta A_o)$ is 10001. If we ignore the 1 we get a closed-loop gain of $100000/10000 = 10$. This is very close to the 9.999 we just calculated. The error is 0.01%, which is almost certainly insignificant in circuits using 5%, or even 0.1%, unmatched resistors, or similar components. Removing the 1 from the feedback equation gives us:

$$A_c \approx \frac{A}{\beta A_o} = \frac{1}{\beta}$$

This result implies the closed-loop gain is not just insensitive to, but totally independent of, the amplifier gain. The relationship $A_c = 1/\beta$ is of course an approximation, but for some circuits, such as op amps at relatively low frequencies, the approximation is both very good and very useful. We can confidently set the gain of a standard op amp amplifier circuits, such as those shown in Fig.2, just by choosing a couple of resistor values. The op amp's gain is so large we do not even have to know what its actual value is.

Standard amplifiers

In the case of the non-inverting standard op amp amplifier (Fig.2) there is no input network (as we assumed earlier) and the feedback fraction is given by the potential divider formula for V_{out} across R_2 and R_1 that is:

$$\beta = \frac{R_1}{R_1 + R_2}$$

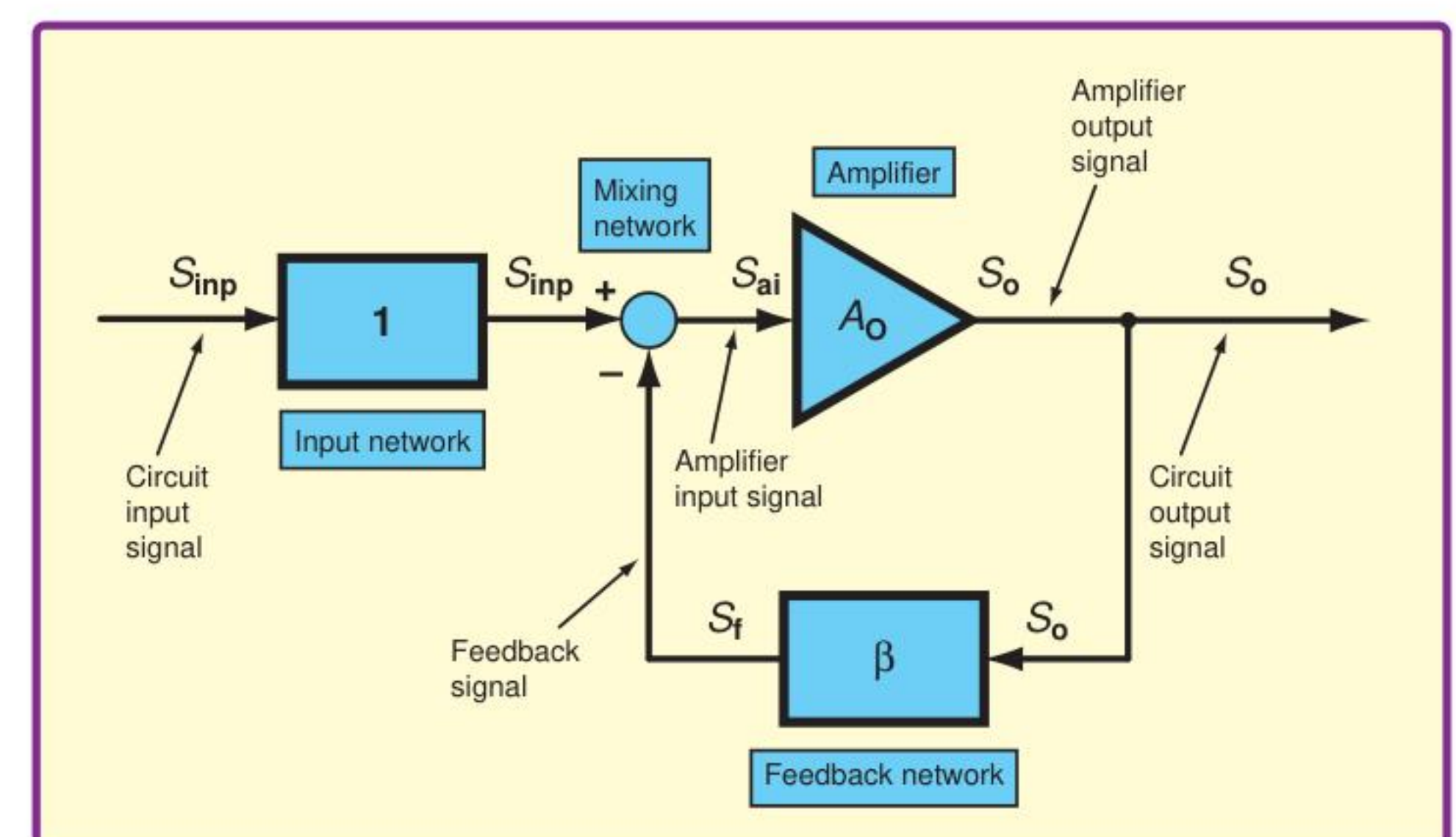


Fig.3. Structure of an amplifier with negative feedback. This example is configured to relate to the discussion in the text where the input network does not exist (does not change the signal), but in general the input network may modify the signal

From which the well known gain formula is easily obtained using $A_C = 1/\beta$

$$\frac{1}{\beta} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$

The situation with the inverting amplifier is a little more complex as the input is connected via the resistors, so the input network exists (it scales the input by $1-\beta$). This means the closed-loop equation is not exactly the same as one derived above. However, the result is similar, with the closed-loop gain being effectively independent of A_O as long as A_O is very large.

The preceding discussion indicates that negative feedback is used to produce more stable and well-regulated systems. However, **lost's** question is related to instability in amplifiers with feedback. Unfortunately, application of negative feedback to an amplifier may result in instability (unwanted oscillations). This is very undesirable and we need an understanding of how it might occur (so we can hopefully avoid it). This will also allow us to answer **lost's** specific question about frequency.

Phase shift

The output of a circuit does not respond infinitely quickly to changes at its input, so any signal fed back from the output to the input will be offset in time with respect to the original input. Consider a simple case in which there is a fixed delay from input to output of the circuit whatever the input signal does (things are usually more complicated than this). Say, for example, this delay was $0.1\mu\text{s}$. If the input frequency was 100Hz then this delay time would be 0.001% of the signal's cycle time and could probably be considered insignificant. However, at 2.5MHz the $0.1\mu\text{s}$ delay is a quarter of the signal's cycle time of $0.4\mu\text{s}$ ($1/(2.5 \times 10^6) = 4.0 \times 10^{-7}$). This would usually be expressed by saying that the circuit had a phase shift of 90° at 2.5MHz (one complete cycle of the waveform is 360°). At 5MHz, $0.1\mu\text{s}$ is half the cycle time of the signal. This is a significant point because a phase shift of 180° is equivalent to multiplying the signal by -1 .

In this context, phase shift represents the delay of a sinusoidal signal through a circuit at a given frequency. If the delay is constant then the phase shift will increase linearly with frequency, but often this is not the case, particularly when considering wide frequency ranges. Engineers commonly use plots of the variation of phase shift with frequency to characterise a circuit's behaviour – such plots can be found in datasheets. For signals other than sinewaves there will be multiple frequency components present. If these are delayed by different amounts the signal will distort. This is important in terms of the overall consideration of phase shift in relation to circuit performance, but as far as basic considerations of stability are concerned we only have to think about the phase shift of sinewaves.

Instability

Consider the total phase shift through the amplifier and feedback network (in Fig.3) as we increase the input signal frequency – in line with the above argument, phase shifts will tend to increase. Once the shift reaches 180° we have effectively inverted our feedback signal – what was negative feedback has become positive feedback. Positive feedback produces oscillation – a circuit provides itself with an input that is self-sustaining. When an amplifier undergoes unwanted oscillations we say it is unstable. Returning to the closed-loop gain equation from above:

$$A_C = A_O / (1 + \beta A_O)$$

If the value of the term $(1 + \beta A_O)$ approaches zero then the value of A_C will tend towards infinity. That is infinite closed-loop gain – this results in oscillation. The condition for which $(1 + \beta A_O) = 0$ is $\beta A_O = -1$. This condition for instability specifically concerns the loop gain, not the closed-loop or open-loop gains. This is another potential source of confusion when considering negative feedback in amplifiers.

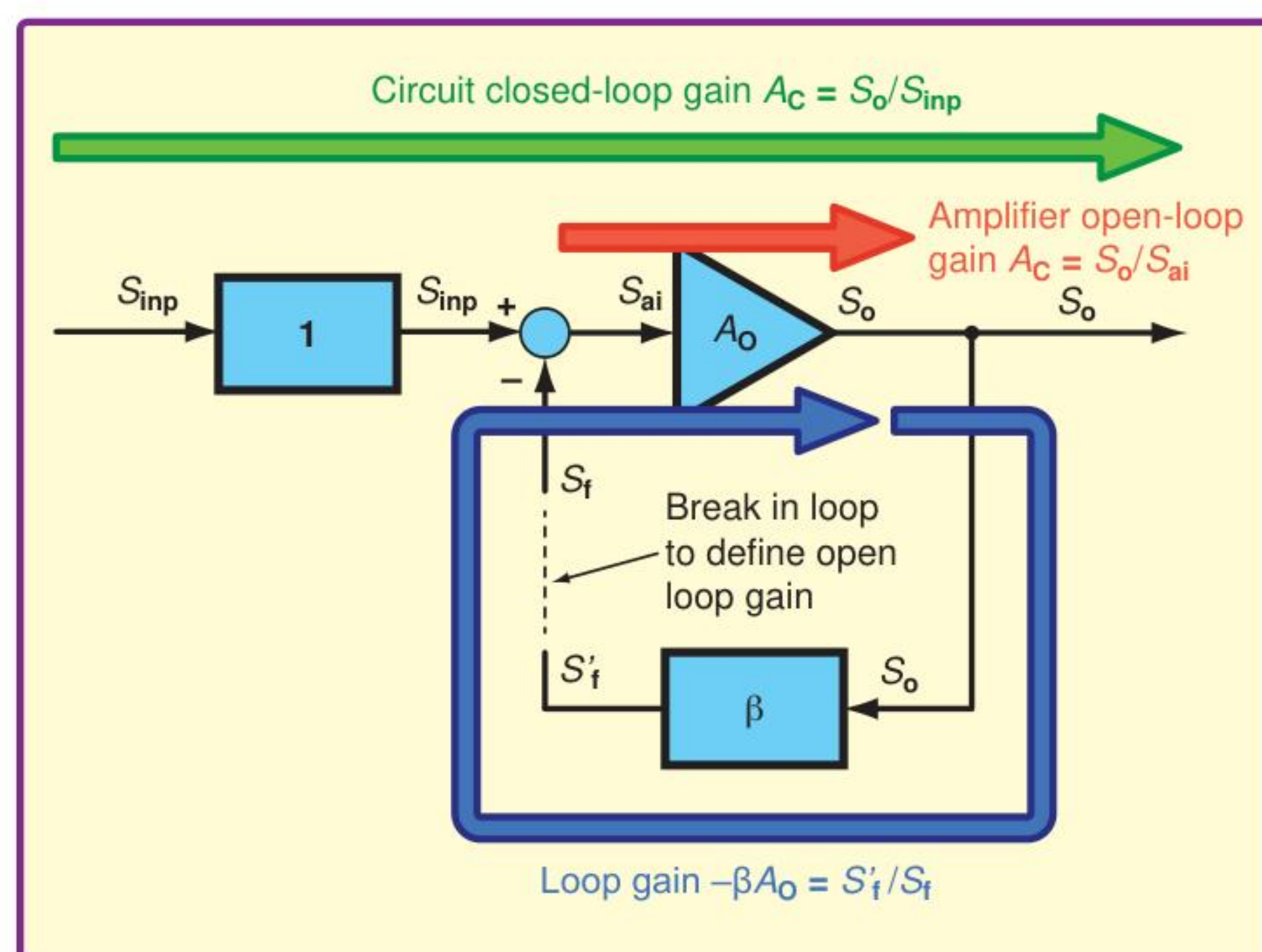


Fig.4. Structure of an amplifier with negative feedback showing open-loop, closed-loop and loop-gain relationships

If an amplifier is unstable and oscillates then the frequency of oscillation will be determined by the frequency at which the above loop-gain condition is met, answering in general terms **lost's** question about amplifier oscillation frequency. The frequency depends on both the feedback network (β) and amplifier characteristics (A_O).

Phase margin and gain margin

Since A_O and β are phasor quantities (they have magnitude and phase shift) we get oscillation when the magnitude of βA_O (loop gain) is at least one (written $|\beta A_O| \geq 1$) and the phase shift due to βA_O is $\pm 180^\circ$. Generally, the gain of an amplifier will decrease and the phase shift will increase as frequency increases. The question is – will the above conditions for instability occur as frequency increases? We can measure how close a circuit is to being unstable using the concept of gain margin and phase margin.

As loop gain approaches 1 the phase shift must be less than 180° . The difference between the phase shift at this point and 180° is the phase margin. Second, as the phase shift around the loop approaches $\pm 180^\circ$, the magnitude of the gain must be less than 1 to prevent oscillation. This difference between the loop gain when its phase shift reaches 180° and a gain of 1 (which is 0 dB) is the gain margin (usually expressed in dB).

Fig.5 shows a frequency response plot for an amplifier loop gain with the gain and phase margins indicated. The gain margin and phase margin are a pair of values for a feedback amplifier that indicate its stability. These values are fixed for a given circuit and do not change with frequency (unlike phase shift and gain). Again, there is a possible source of confusion between phase shift and phase margin.

Poles and zeros

In the gain plot in Fig.5 there are a couple of breakpoints where the gain starts to decrease more rapidly as frequency increases. These breakpoints are called 'poles' and, in simple terms, each can be thought of as relating to a single RC low-pass filter somewhere in the signal path. At frequencies above the pole frequency, gain decreases at a rate of 20dB per decade more compared to below it, and the phase shift is increased by 90° . There is another type of breakpoint that can occur in frequency responses. This is called a 'zero'. Gain will decrease at a rate of 20dB per decade at frequencies below the zero frequency compared to above it (or increase faster if it was already flat or increasing).

Adding poles and zeros to a circuit's feedback loop will change the stability of the circuit. For example, adding a pole may make a circuit more unstable because it causes a phase shift to increase, however it also may make the circuit more stable because the gain is reduced at high frequencies. The actual situation will depend on the relationship of the all the poles and zeros in the frequency response.

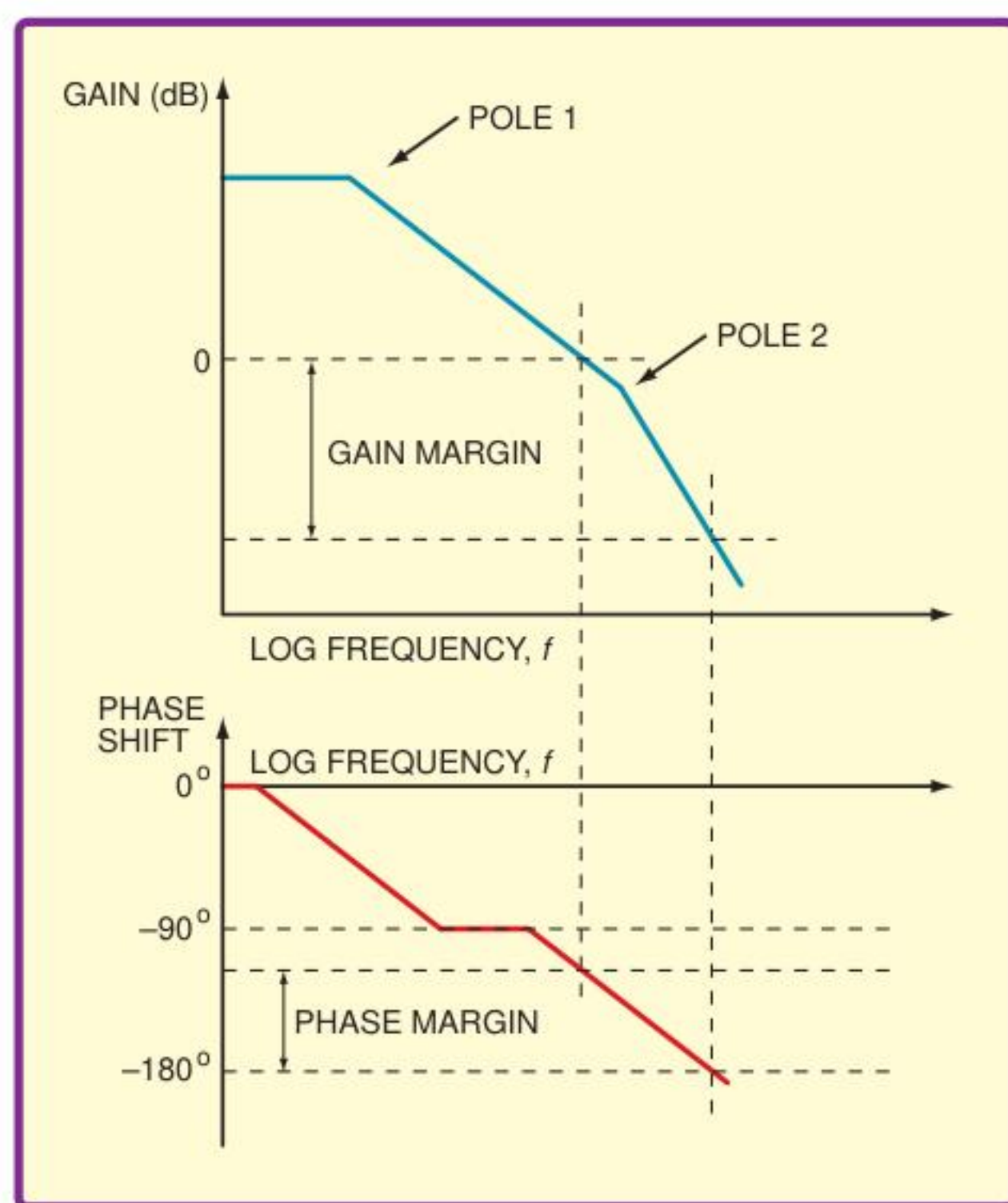


Fig.5. Variation of gain and phase shift around a feedback loop (loop gain) with signal frequency, illustrating gain margin and phase margin

A common source of stability problems is capacitance at the output of the amplifier or feedback network, both of which increase phase shift, reducing phase margin. These may be parasitic capacitances (eg, from wiring or cables) or capacitive loads in the case of the amplifier output. Capacitance across the feedback resistors in the basic op amp configurations (R_2 in the circuits in Fig.2) helps prevent instability by reducing gain as frequency increases.

If a circuit has poor gain and phase margin then it may not oscillate all the time, but things such as changes in temperature and component aging may make things worse, leading to sustained oscillation. Furthermore, a circuit with poor gain and phase

margin is likely to ring (produce decaying oscillations) if large input signal changes occur. If the frequency response is completely unstable (no gain, or negative gain and phase margin) it will oscillate permanently.

Low gain

In our initial discussion we noted that a small feedback fraction (small β) resulted in a large closed-loop gain for the amplifier circuit. This also follows from the $A_C = 1/\beta$ expression which we obtained earlier (applicable to the non-inverting op amp configuration). Conversely, a low closed-loop gain circuit has higher β (β closer or equal to 1) and hence higher loop gain. The higher loop gain means the low-gain circuit is more likely to be unstable. Worse instability for low closed-loop gain may seem counterintuitive if we think of something with high gain as being 'unstable' because it is very sensitive to its inputs etc. Increasing the gain of a suspected unstable op amp circuit in a prototype to stabilise it can be used to help diagnose stability problems.

Some commercial op amps are not designed to be stable in low closed-loop gain configurations (eg, gains at or below 2 or 5.). This is done specifically to allow higher-gain, closed-loop gain circuits to have higher bandwidth (the open-loop gain A_O can be higher at higher frequencies with smaller β values because the loop gain βA_O is still sufficiently small there to achieve a good gain margin). This is a potential pitfall for those who do not read datasheets carefully enough to notice the minimum close-loop gain specification.

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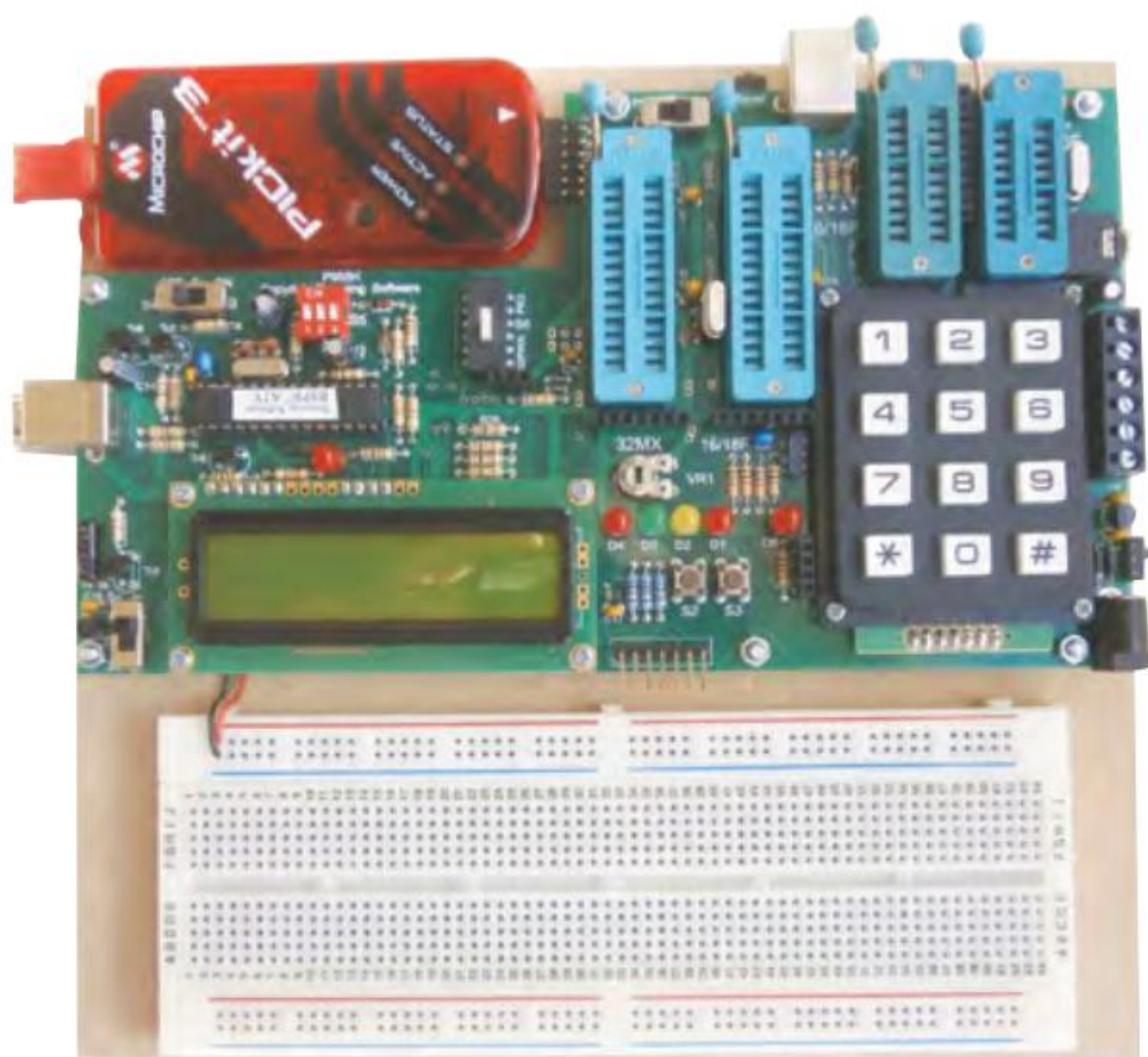
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32 bit PIC Training

by Peter Brunning



32 bit PICs are massive in all respects. Huge amounts of programme memory, huge amounts of temporary storage memory (RAM), huge amounts of input/outputs, and very fast processing speeds. And fortunately for us experimenters Microchip have included a dual in line version.

The problem is that 32 bit PICs are far too complex for absolute beginners. So the P955 training circuit has been designed to work with both 32 bit and 8 bit PICs. The idea is to start learning about PICs using assembler with 8 bit PICs. Then learn C with 8 bit PICs, study serial communications using 8 bit PICs, and finally study C programming using 32 bit PICs. It is a simple approach to a subject that has no limit to its ultimate complexity.

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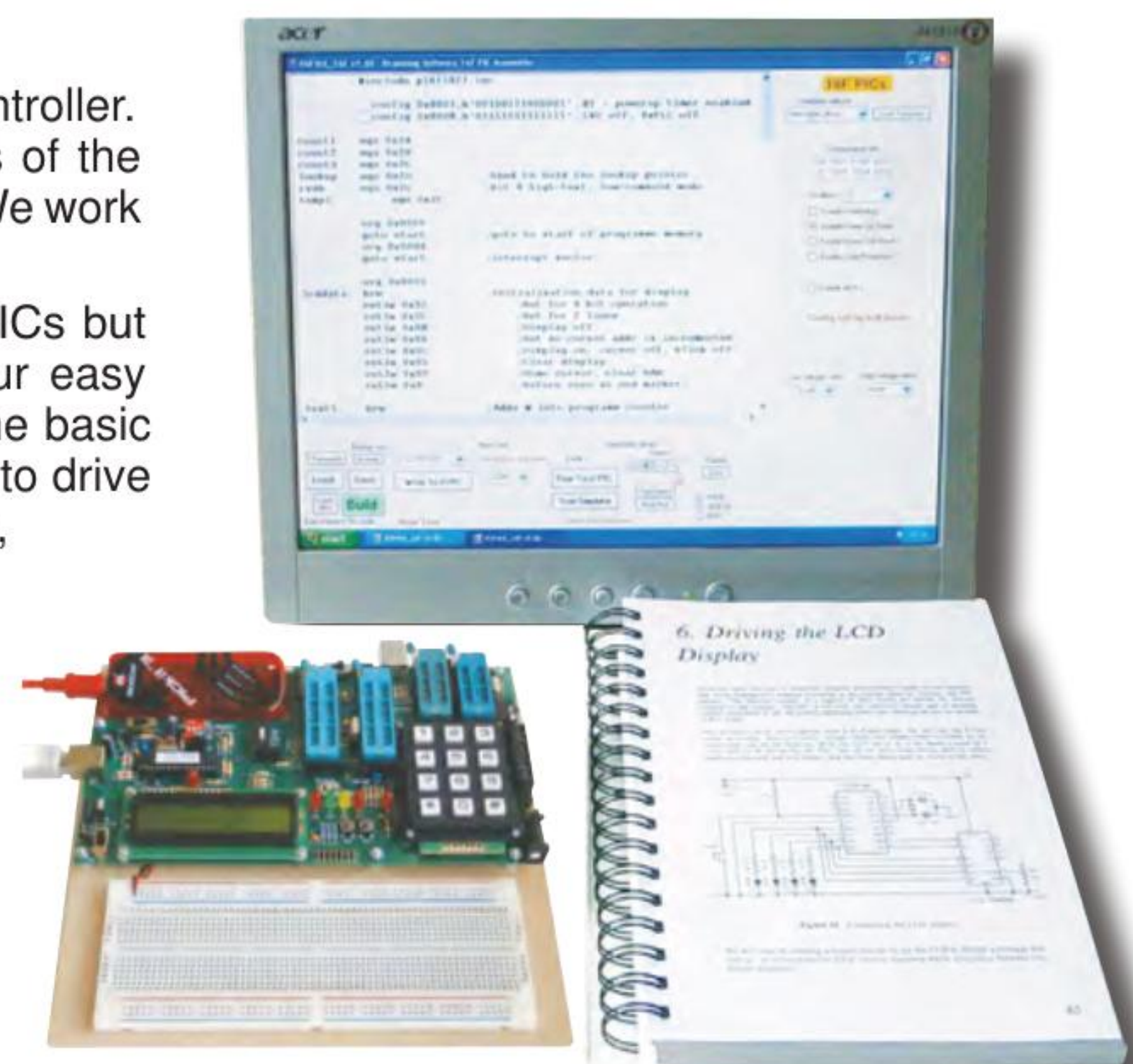
The second book introduces the C programming language for 8 bit PICs in very simple terms. The third book Experimenting with Serial Communications teaches Visual C# programming for the PC so that we can create PC programmes to control PIC circuits.

In the fourth book we learn to programme 32 bit MX PICs using fundamental C instructions. Flash the LEDs, study the 16 bit and 32 bit timers, write text to the LCD, and enter numbers using the keypad. This is all quite straightforward as most of the code is the same as already used with the 8 bit PICs. Then life gets more complex as we delve into serial communications with the final task being to create an audio oscilloscope with advanced triggering and adjustable scan rate.

The complete P955H training course is £254 including P955H training circuit, 4 books (240 × 170mm 1200 pages total), 6 PIC microcontrollers, PIC assembler and programme text on CD, 2 USB to PC leads, pack of components, and carriage to a UK address. (To programme 32 bit PICs you will need to plug on a PICkit3 which you need to buy from Microchip, Farnell or RS for £38).

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PICs and the PICkit 3: A beginner's guide – Part 6

WE'VE SPENT the last few months working through the first few lessons in the *PICkit 3 Low Pin Count Demo Board User Guide*. We've looked at controlling some LEDs and running various light sequences with them. So, what can we do with this new knowledge, and how is it useful? This month, we're going to take a step back from the lessons and put the techniques discussed into use. The goal here is to take what we've learnt, change it ever so slightly to help us understand what's going on and demonstrate a real-world example.

A reasonable starting point is simply to ask, 'where are microcontrollers like the PIC used?' A good example is a set of traffic lights – a simple, but powerful tool used to control the flow of vehicles. If we really wanted to, we could control every set of traffic lights using the same Demo Board that we've been using. We'd be missing a few key components, like power supplies, relays to control the lights themselves and a few other items, but the control system at the heart of all traffic lights really is as simple as a single microcontroller like our PIC.

Basic flow diagram

We can design and build our own traffic light system by starting off with a flow diagram, which will set out the states the traffic lights will operate from. To draw the flow diagram, we need to know the states of the individual lights that make up the traffic light – the red, amber and green. In Fig.1, we start with a green light at the top, then transition to a flashing amber light, then onto a red light and finally back to green again.

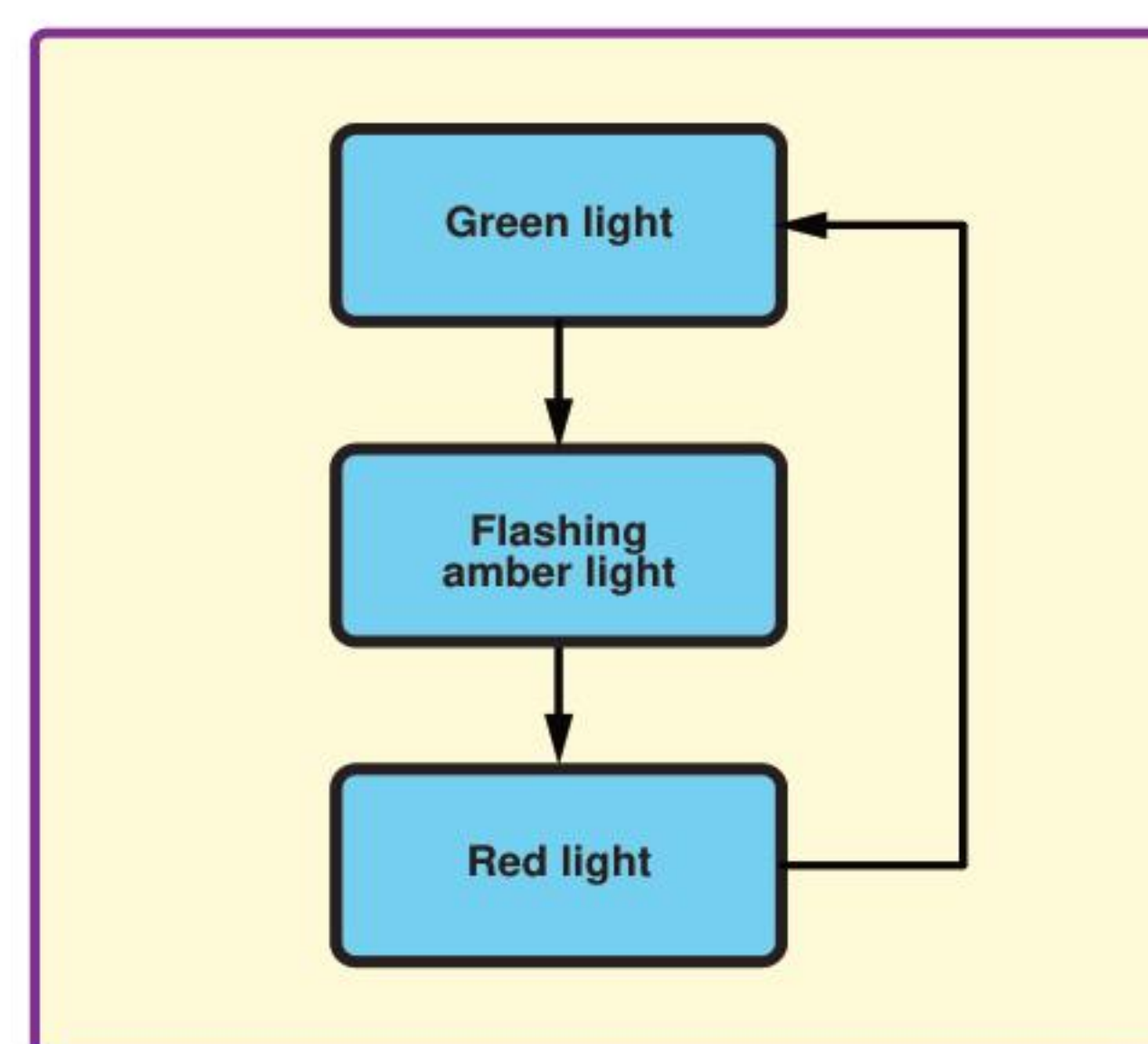


Fig.1. Basic traffic light sequence

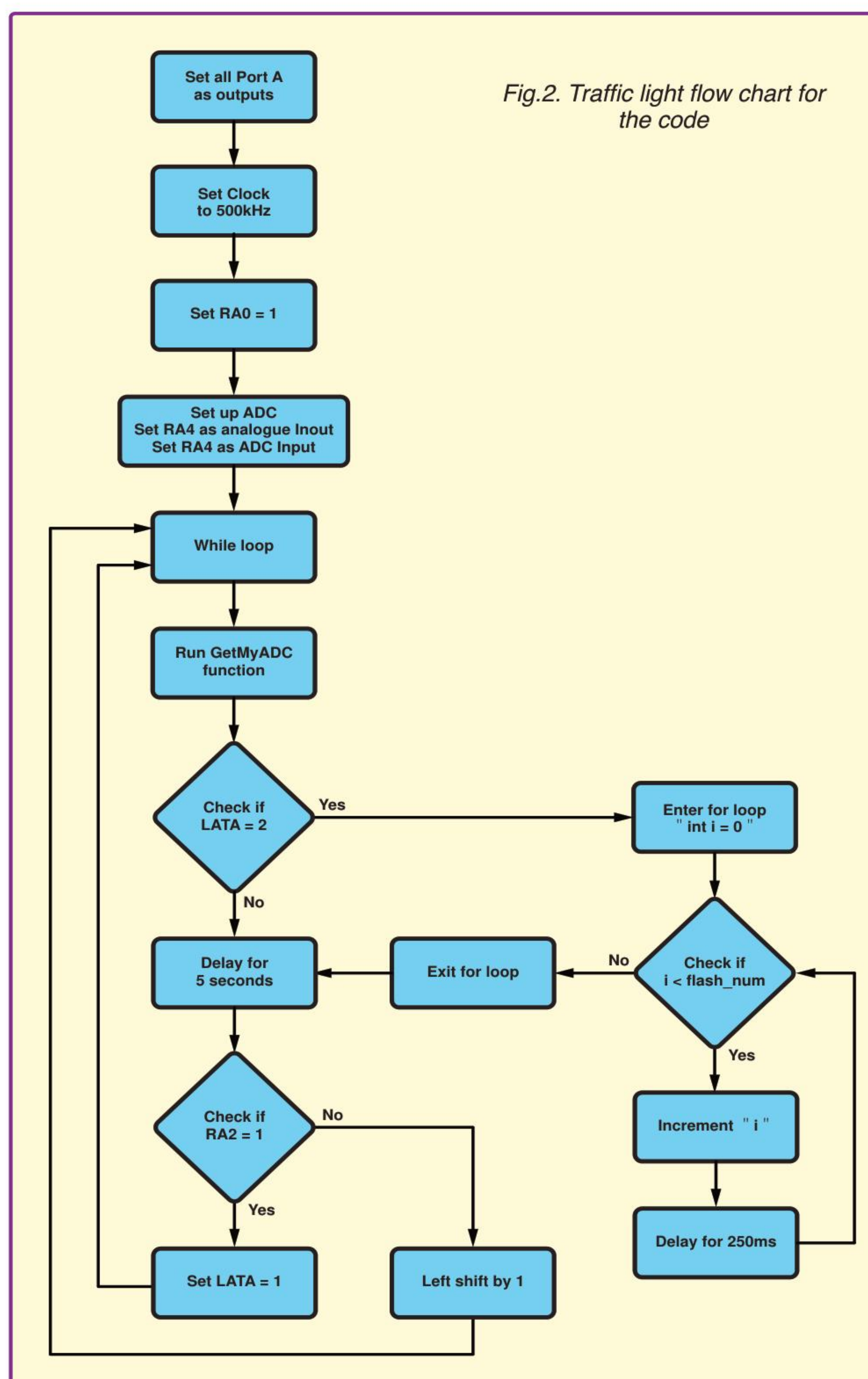


Fig.2. Traffic light flow chart for the code

When the light is green, we know it's safe to go, when it's amber, we get ready to stop and we stop on red. (I'm using a flashing amber light instead of the standard solid amber light, for effect and to use our new coding skills.)

Detailed flow diagram

Now that we know the light sequence, we can draw a more complicated flow diagram to help us figure out how to do this in the code – Fig.2 shows what we want to achieve. We could start

from any position, since our system will continually cycle around the three lights. Choosing green as the start position, we choose a time for it to be lit. Five seconds should suffice for our example. Then we flash the amber light to prepare the driver to stop. Using the code we learnt in previous lessons, let's adjust how many flashes are seen with the ADC input, which is connected to the on board potentiometer. This will dictate how often amber flashes. Once the amber has completed flashing, we can turn on the red light to tell drivers to stop. The cycle of rotation between the three LEDs is repeated indefinitely.

I know that in reality five seconds would barely give the average driver enough time to shift into first gear, release the hand brake and accelerate through the lights, unless they're a Formula 1 driver, competing in the Grand Prix. We could swap the five seconds for five minutes for a more accurate representation of the lights, but keeping it in seconds allows us to see the fruits of our efforts much quicker.

Back to the flow diagram in Fig.2; it's similar to what we've done in the past, except with a little more going on now. We're going to take our rotating LEDs and ADC lessons and merge them together. Instead of using Port C, we're going to use Port A. This stops us from lighting the on-board LEDs, which are connected to Port C. We start by setting all of the bits on Port A to outputs. Next, we set the clock just as we have done in the past. Instead of right shifting through our options, we're going to invert the direction and use left shift. This means we move from RA0 (also known as bit '0' on Port A) leftwards to RA2. To start the shifting, we need something to shift, so we set a '1' in RA0. The green LED will be represented by RA0, RA1 will be amber and RA2 red. See Fig.3 for a diagram on left shifting, and Fig.4, which illustrates Port A's individual bits.

Before we start shifting through the LEDs, we must set up the ADC input. Using the potentiometer as in Lesson 4 on ADCs, set up RA4 as an analogue input and as the ADC input.

Now we enter the `while` loop and start off by calling a function called `GetMyADC`. (I'll discuss functions later on.) For now, all we need to know is that this function gets our ADC value and stores it in a variable called `flash_num`.

The next step in the flow diagram is to check if Port A is equal to 2 (note that here the number two in binary is written as 0010). This is another method to reference the registers in the code. Alternatively, we could use the following lines, which result in the same thing:

```
if (LATABits.LATA1 == 1) { ... }
if (LATA == 0b00000010) { ... }
```

In Fig.4 we see that we're actually referring to RA1, which is the amber light. If the check is `true`, then we enter a `for` loop. This `for` loop will

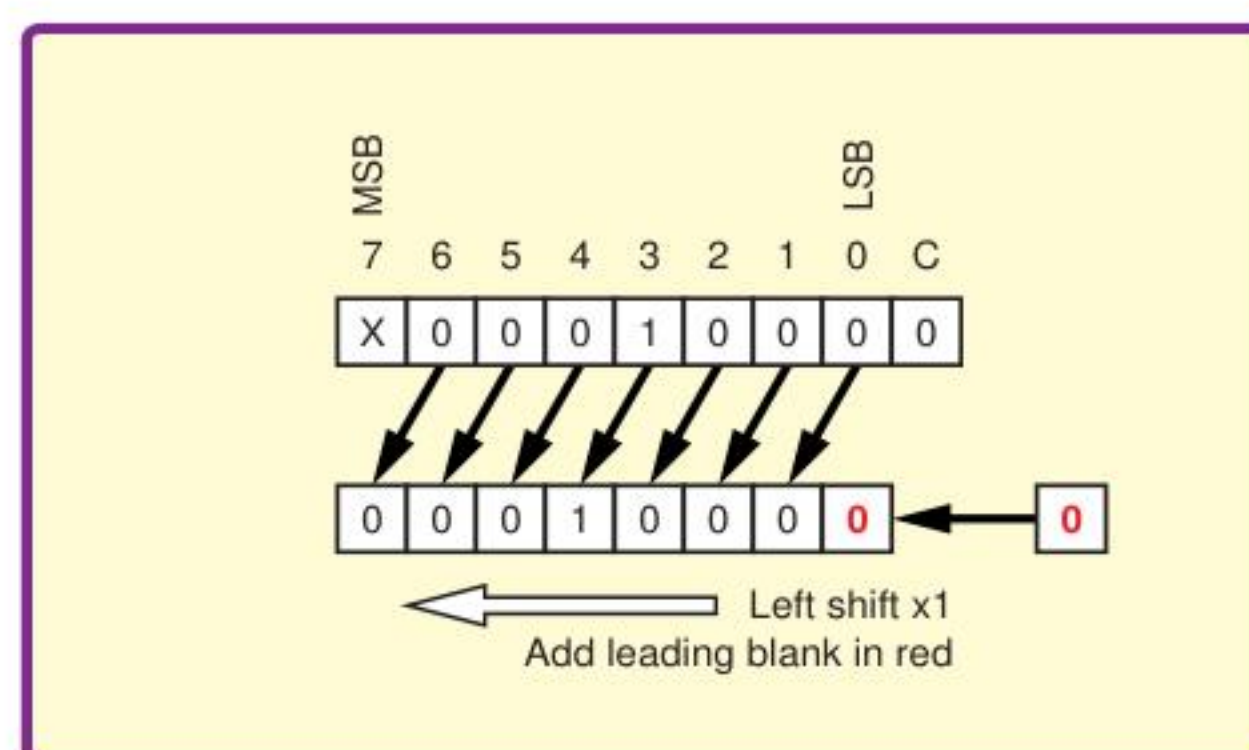


Fig.3. Left-shifting diagram

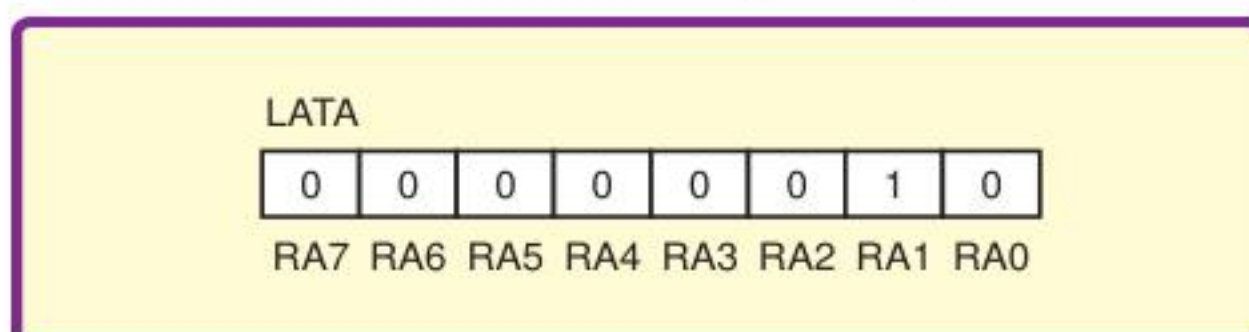


Fig.4. Port A bits diagram

run for as many times as the `flash_num` variable obtained from the `GetMyADC` function. When the amber LED has flashed the correct number of times, we exit the loop and continue with the rest of the code after waiting for five seconds (thus holding the LED).

We control the state of Port A by checking to make sure we only use RA0, RA1 and RA2. Starting off at RA0 and left shifting to RA1 and RA2, moves us from the green LED, to the amber and red. Once we've completed the five-second wait on the red LED, we want to move back to the green LED. The program does this by checking if RA2 is equal to '1'. If it is, it sets LATA to 0b001. Otherwise, it performs the normal left shift and restarts the `while` loop.

The code

The full code can be downloaded from EPE's website, let's examine it in detail. We've seen a lot of this code already in

our previous lessons – LED rotate and using the ADC. This code is our main loop, which follows the flow diagram in Fig.2. Listing 1 starts off with two new items, initialising the function `GetMyADC` and a global variable `flash_num`.

The global variable

We know from previous lessons that a variable is a word in our code that can store a value. This variable can be a `char`, `short`, `int`, `long`, `double` or `float` type, indicating the number of bytes it can represent. These variables can be signed (plus or minus) or unsigned (all plus). Normally, we initialise our variable inside the main loop or inside a function, but this means the variable can only be used where it is initialised (unless we pass the variable back and forth through functions, but that complication is a discussion for another day). By initialising the variable outside the main loop and function, it can be accessed by any part of the program, thus making it global. This can be problematic because multiple functions could try and use and edit the same variable at the same time, which will cause all sorts of problems – always be careful about where and how you initialise and use variables.

In our code, the `GetMyADC` function obtains a value from the ADC and stores it in `flash_num`. This value is then read in the main loop to determine the number of flashes of the amber LED.

Our first function

Now is the perfect opportunity to add a function – but what is a function? A

Listing 1. Traffic light code

```
void GetMyADC (void);
unsigned int flash_num = 5;

void main(void) {
    TRISA = 0;
    OSCCON = 0b00111000;
    LATA = 0b00000001;

    TRISAbits.TRISA4 = 1;
    ANSELAbits.ANSA4 = 1;
    ADCON0 = 0b00001101;
    ADCON1 = 0b00010000;

    while (1) {
        GetMyADC();

        if(LATA == 2){
            for (int i = 0; i < flash_num; i++) {
                delay_ms(500);
                LATABits.LATA1 ^= 1;
            }
            LATA = 0b010;
        } else {
            __delay_ms(5000);
        }

        if(LATABits.LATA2 == 1){
            LATA = 0b001;
        } else {
            LATA <<= 1;
        }
    }
}
```


function is a piece of code wrapped up in brackets that can be called time and time again.

```
void GetMyADC (void) {
    __delay_us(5);
    GO = 1
    while (GO) continue;
    flash_num = (ADRESH >> 4);
}
```

A function is declared outside of the main loop and can be called from within the main loop as follows:

```
GetMyADC();
```

The function `GetMyADC` gets the ADC value from RA4 and stores it in the ADRESH and ADRESL registers that we looked at last month in Lesson 5. The code is exactly the same, except we've wrapped it up as a function and changed the variable name we store our MSBs (most-significant bits) of ADRESH to `flash_num` (as a reference to the number of times the amber LED will flash). It's always a good idea to give your variables meaningful and descriptive names as it can aid in reading and understanding the code.

The for loop

Once the function has finished, we return to the `while` loop, where we check to see if the amber LED is selected (`if(RA1 == 1)`). If it is, then we want to flash the LED based on the value stored in `flash_num`. This is where the `for` loop comes in.

```
for(int i = 0; i < flash_num; i++) {
    ...
}
```

The `for` loop is another loop function, similar to the `while` loop we've used before. This loop is a little different, in that we use a variable to control the number of times we go round the loop. In this case, the letter `i` is our variable. We start by initialising it to 0, check if it is less than `flash_num` and then increment it (add 1 to it). Once the code inside the loop has been completed, the loop starts again, checks if `i` is less than `flash_num` and increments if not. This continues until `i` is greater than or equal to `flash_num`. So if `flash_num` is equal to 15, our loop will run $15+1=16$ times.

In the `for` loop, we toggle RA1 on and off using the `^` operator. This is a shorthand method of changing the output of RA1 to a logic high, when it is low, or to a logic low when

it is high. This gives us our flashing amber LED. Once the loop finishes, we return to the rest of the code.

In the next piece of code – `if(LATAbits.LATA2 == 1)` { – we check to see if we've reached the left-most of our three LEDs (see Fig.4). If we have, we reset the three LEDs back to 0, except for RA0, which should now be 1: `LATA = 0b001;`

If we haven't reached the end of our sequence, we use the left shift operator to select the next LED: `LATA << = 1;`

This is almost identical to the right shift that we learned about in previous lessons, except it shifts everything to the left instead.

An interesting point to note here is the status of RA4, which is our ADC input. This also happens to be on Port A. We need to make sure we don't try and write to this register by accident. This is why we use `LATA = 0b001;` instead of `LATA = 1;` or `LATA = 0b00000001;` These may seem like the same command, but, `LATA = 0b001` only writes to RA2 (0), RA1(0) and RA0(1). Whereas both `LATA = 1;` and `LATA = 0b00000001` write to the whole 8-bit register from RA7 to RA0, including RA4, which is the ADC input. This will cause erratic behaviour in the code if we're not careful.

The hardware

It's time to build our traffic light system. We need three LEDs, a green, amber and red one, plus three 330Ω resistors for current limiting. Fig.5 shows the layout of the Demo Board and the resistor/LED connections.

Fig.6 shows the finished project. For effect, I borrowed the cars from a friend's son and built a little road out of black cardboard and electrical tape. The traffic light is a bit of black cardboard mounted on a BIC pen. The wiring for the LEDs goes up through the pen, and I think it does the job quite nicely.

Next month, we'll return to the Microchip series of lessons, but before I sign off I'd like to address a great question asked on the forums (by **grahamrounce**) regarding the use of other development boards from Microchip, specifically Microchip's 'Curiosity Board', and if using this board will adversely affect the following of the guide as we progress. The

Curiosity Board and the Low Pin Count Board both use pin compatible PICs, although the devices are slightly different. All the code segments we've used so far should work, but you just need to make sure you change the configuration in MPLAB X IDE to use the PIC16F1619 instead of the PIC16F1829. Compared to the Low Pin Count Board, the Curiosity Board uses the same LEDs, potentiometer and buttons, all connected to the same pins.

Next month

In the next *PIC n' Mix* column we'll move on to Microchip PIC Lessons 5 and 6, which cover variable speed rotating LEDs and button debounce. After that, we'll move away from LEDs and on to much more challenging lessons like timers, PWM and interrupts. Then, we'll come back with another project in a few months to demonstrate our newfound skills.



Fig.6.
Finished
and working
traffic light
example

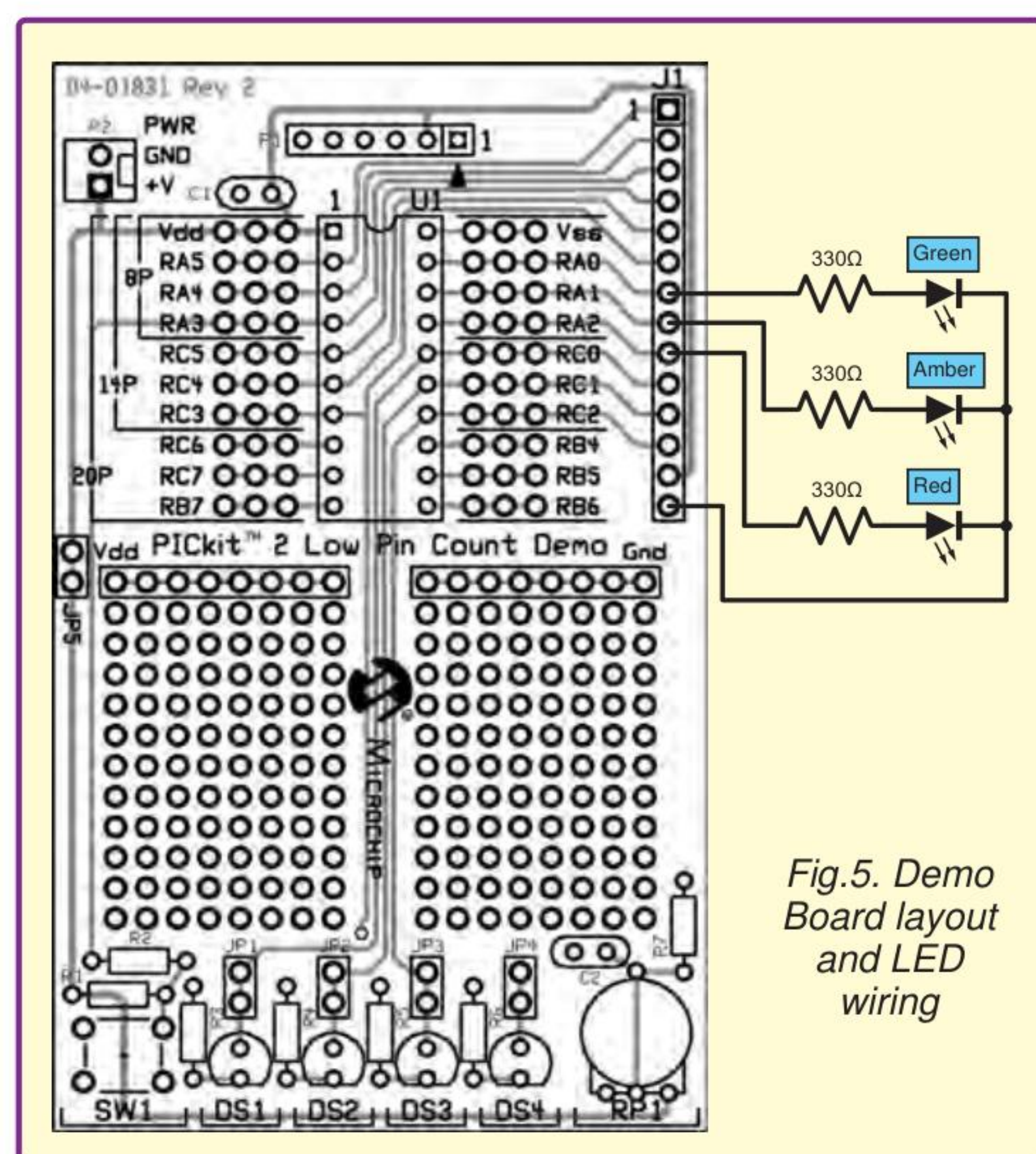


Fig.5. Demo
Board layout
and LED
wiring

Not all of Mike's technology tinkering and discussion makes it to print.

You can follow the rest of it on Twitter at @MikePOKeeffe, up on EPE Chat Zone as *mikepokeeffe* and from his blog at *mikepokeeffe.blogspot.com*

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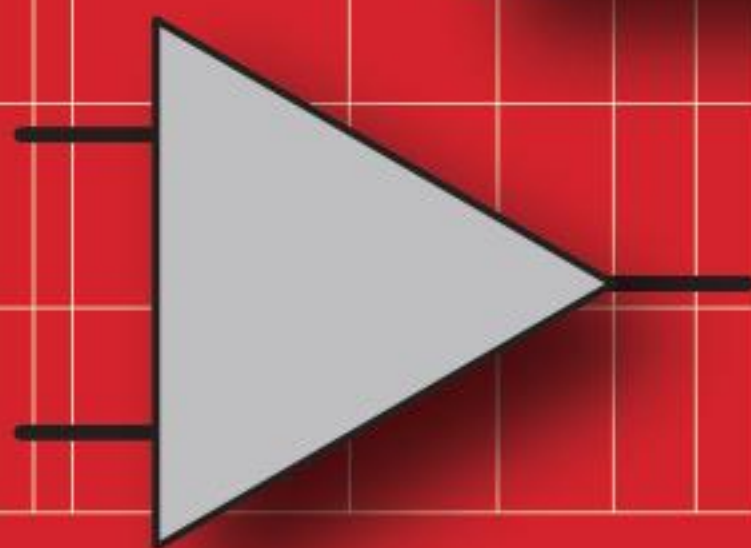
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AUDIO OUT



By Jake Rothman

Hobby Creek Hands product review

It can be truly frustrating trying to solder wires to small fiddly components like headphone mini-jacks or even small circuit boards. My college students sometimes make component support clamps out of thick wire screwed into a terminal block, finished off with crimped crocodile clips, as shown in Fig.1. These primitive constructions avoid the need for the proverbial 'third hand'. For those of us who need something more sophisticated and permanent, Hobby Creek has provided solutions in the form of the Mini Hand, the Third Hand and the Pana Hand (in order of increasing capability and cost). They are a ready-made alternative to the Spark Fun third-hand kit, which requires assembly work. The units are not cheap, but they are top quality and are now available in the UK.

Construction

The clever idea behind these products is the use of Loc-Line (see Fig.2), which is a special multi-segmented plastic bendy pipeline often used to direct cutting fluid on machine tools. It's strong enough to hold small PCBs (see Fig.3) and although flexible, it is stiff enough not to sag. Since it's made of plastic it will be damaged if a soldering iron is pressed against it, but accidental contact and the occasional solder blob does not cause any problems. The orange plastic component initially worried me – it's where the line is screwed into the base – but in fact it's machined from an exceptionally tough plastic, so I don't anticipate its thread

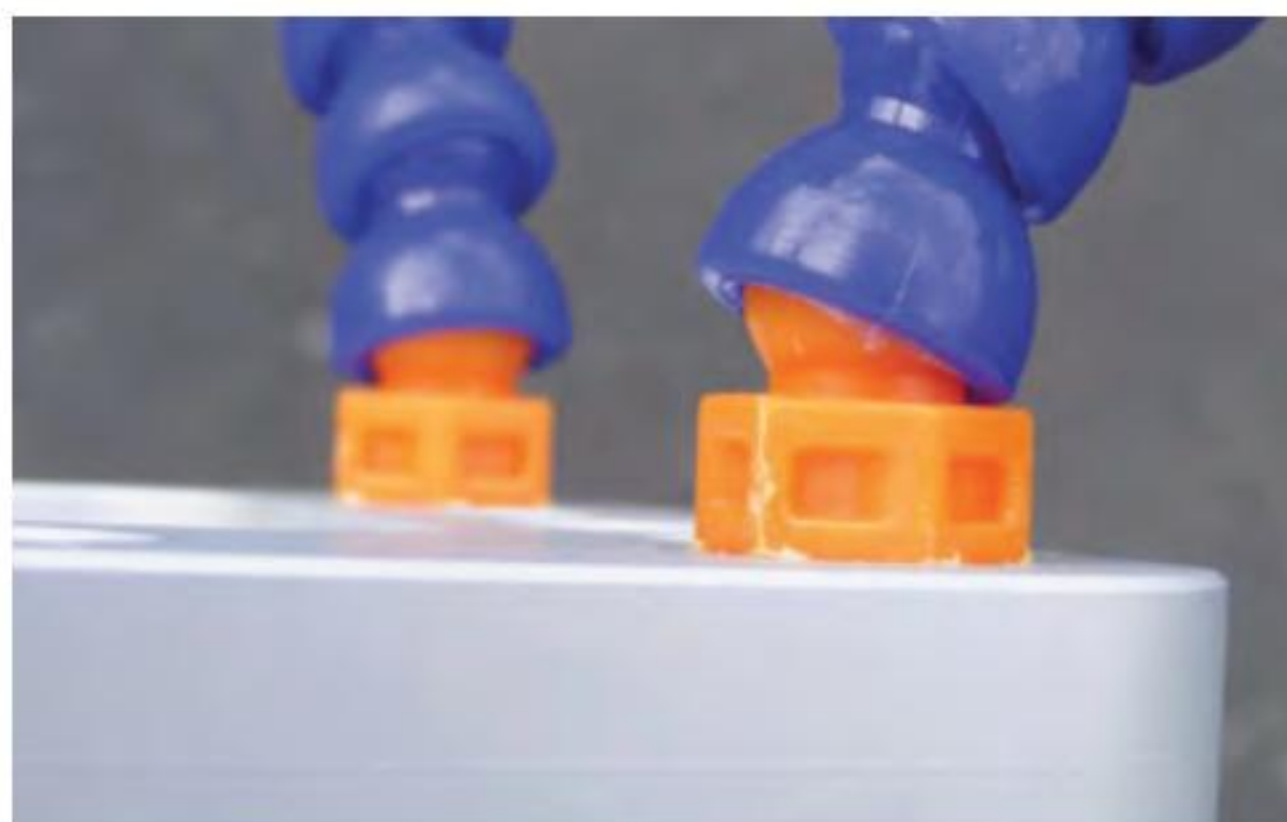


Fig.2. Loc-Line, a special (blue) piping used in mechanical engineering

stripping (the holes in the metal bases are tapped with a US imperial thread of 1/2-inch 20TPI).

In use

The silicone sleeves on the crock clips didn't melt at all and provide excellent grip without scratching, as shown in Fig.4. Generally, the degree of stiffness of the assemblies was just right for most work and successfully held reasonably large PCBs. I found it useful to lubricate the arms in the middle with a little PTFE grease for delicate work. The assembly is robust and I suspect only the (replaceable) croc-clips will fail with time – the usual bent jaws and loss of springiness associated with long-term use of such components.

The croc-clips screw on (Fig.5), which means other items can easily be attached to the arms. Being over 50, I

decided to attach a magnifying glass to mine. I suggested this option to Danial Stein at Hobby Creek, and he said he was thinking of doing one. I told him it had to be glass; plastic lenses are no use when there's solder stuck to them – a problem I've experienced with cheap Chinese third-hand units available from many distributors.

Fume extractor

I toyed with the idea of connecting my solder fume extraction line to one arm so I could take the clumsy tube off my iron. However, I was also sent a USB fume remover using the same arm arrangement, as shown in Fig.6. This is powered via a micro-USB socket on the side. (A two-metre lead was provided). It proved to be effective since it could be placed right next to the fume source, and at only 50mm square it's also very compact. The filter was a piece of activated-charcoal-impregnated foam matrix similar to the type used in some cooker hob filters, and a spare was provided in the pack. I found the fan to be a little noisy for my sensitive 'audio guy' ears, but I'm sure I could learn to live with it.

Best buy

The Mini Hand is the most cost-effective version, with just two arms

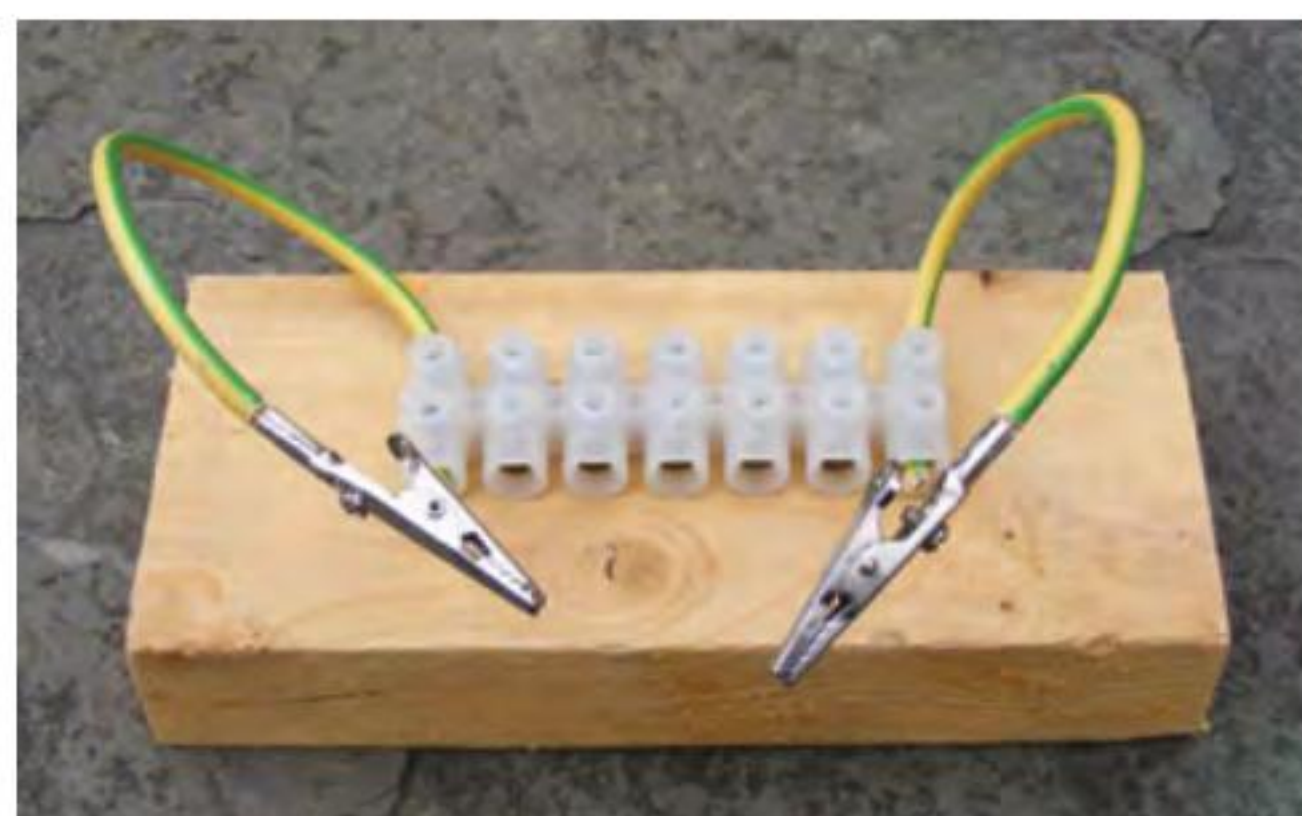


Fig.1. The old way of making a 'third hand'.

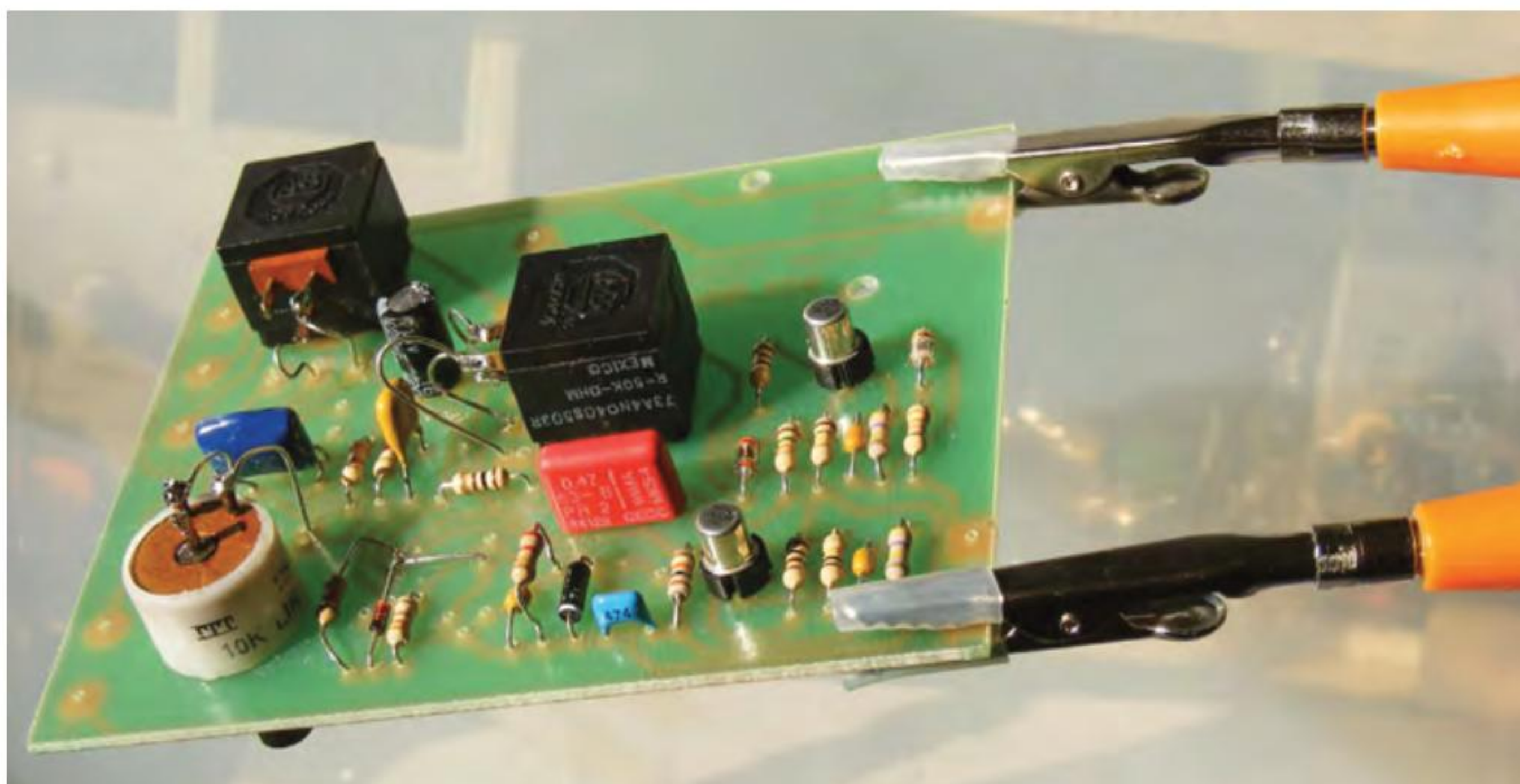


Fig.3. The Hobby Creek system will comfortably hold a small PCBs



Fig.4. The silicone rubber sleeves on the croc-clips is a nice touch



Fig.5. A bolt in the Loc-Line attaches the croc-clip or other accessory

and a small sticky aluminium base; it went straight in my mobile studio tool case. The Third Hand (Fig.7) has a heavy base and is my favourite. The Pana Hand is lighter and better looking (Fig.8) but needs to be bolted down. Bolts are supplied, but are too short for the typical 19mm UK workshop desk. I mounted my Pana Hand to the bench with M6 countersunk bolts using the three holes provided with T-nuts pressed into the bench underneath.

I'm going to take the units down to my Audio Electronics class at the University of South Wales. It may become an exercise in destructive testing, but I have confidence they will survive, and I'm assured any spare parts required will be available.

Like most engineers I've got a 'cup-board of regret' containing hundreds of pounds (or more) of useless tools that looked great, but which I never use – for example, a £200 PCB crop-bend tool which made an ear splitting crack on every lead, never to be used again. However, I use the Hobby Creek units at least once a week, which shows their value is assured.



Fig.6. The Hobby Creek fume extractor screws into the base

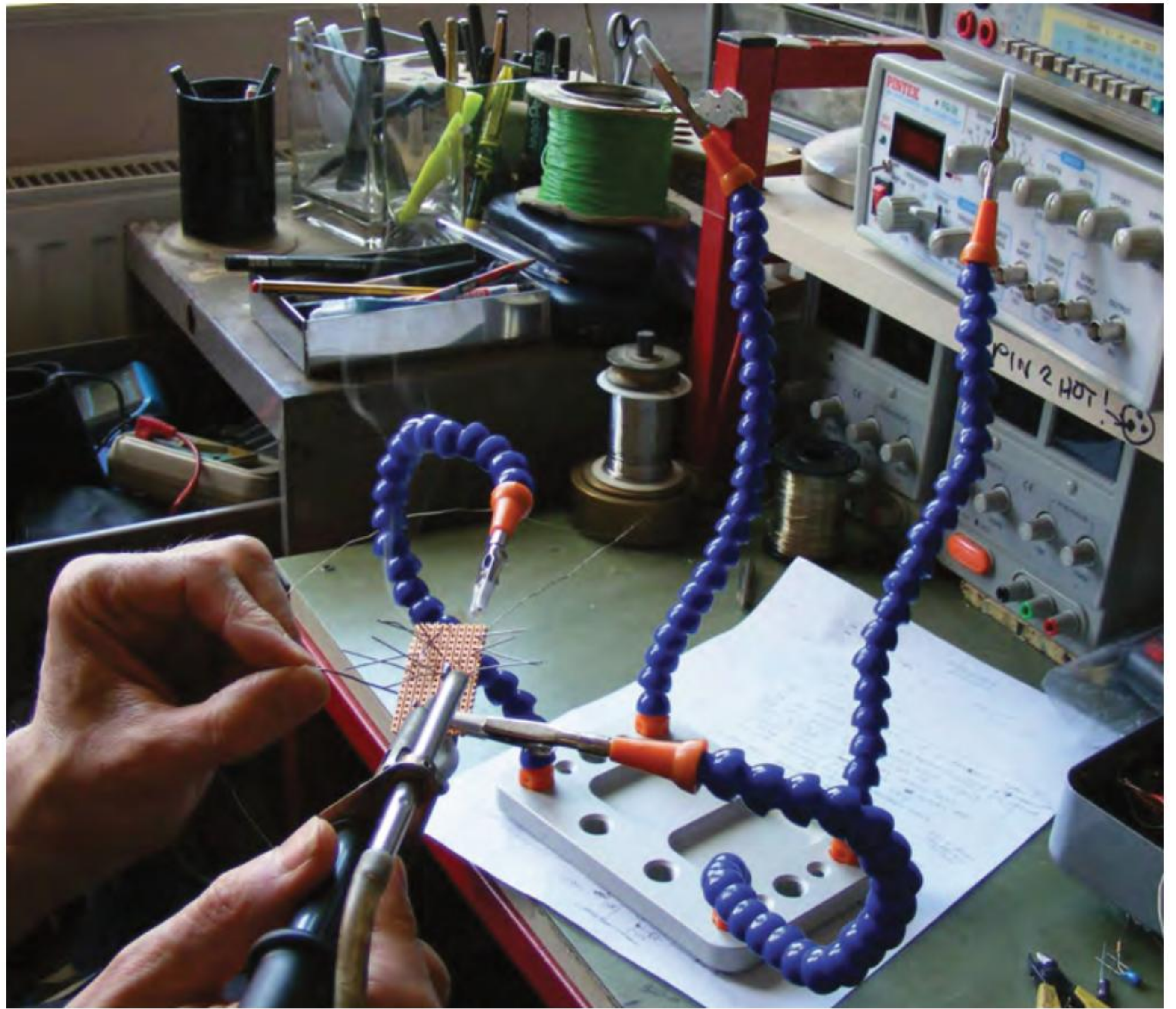


Fig.7. The Third Hand – recommend for most workshops

Source and price

These items are priced in US dollars and using a conversion rate of 0.75, the prices are £22.50 for the Mini Hand and the fume extractor, and £33.70

and £42.00 for the Third and Pana Hands respectively – plus the usual delivery and VAT.

More details are available at: www.hobbycreek.com



Fig.8. The Pana Hand allows most Pana-Vise accessories to be attached for a more flexible and sophisticated set-up

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High-side current transducer

AN ARTICLE last year in *Circuit Surgery* (March-April 2015) on constant-current sources called to mind a circuit I developed about 15 years ago, which is – as far as I know – unique. At the time, I wondered whether there was any mileage in applying for a patent, but I didn't take it any further and much water has passed under the bridge since.

I needed to monitor the current on the supply side of an unregulated DC circuit, with the floating voltage outside the supply rail of the monitoring circuit. One way to do this would be to use a current-sensing resistor and then measure the voltage (relative to ground) at either side of it, subtract one from the other and then divide by the value of the sense resistor. This could be done using two ADC inputs of a microcontroller, but the input voltages would need shifting into the input voltage range of the micro using potential dividers (Fig.1). This has the problem that (for a sufficiently small sense resistor) a very small part of the input range for the ADC will be used (resulting in the current measurement having poor resolution), and the potential divider resistors would need matching to a high precision if the division-ratio errors are not to swamp the current-sense voltage.

I came up with is a unique three-terminal circuit using two pairs of

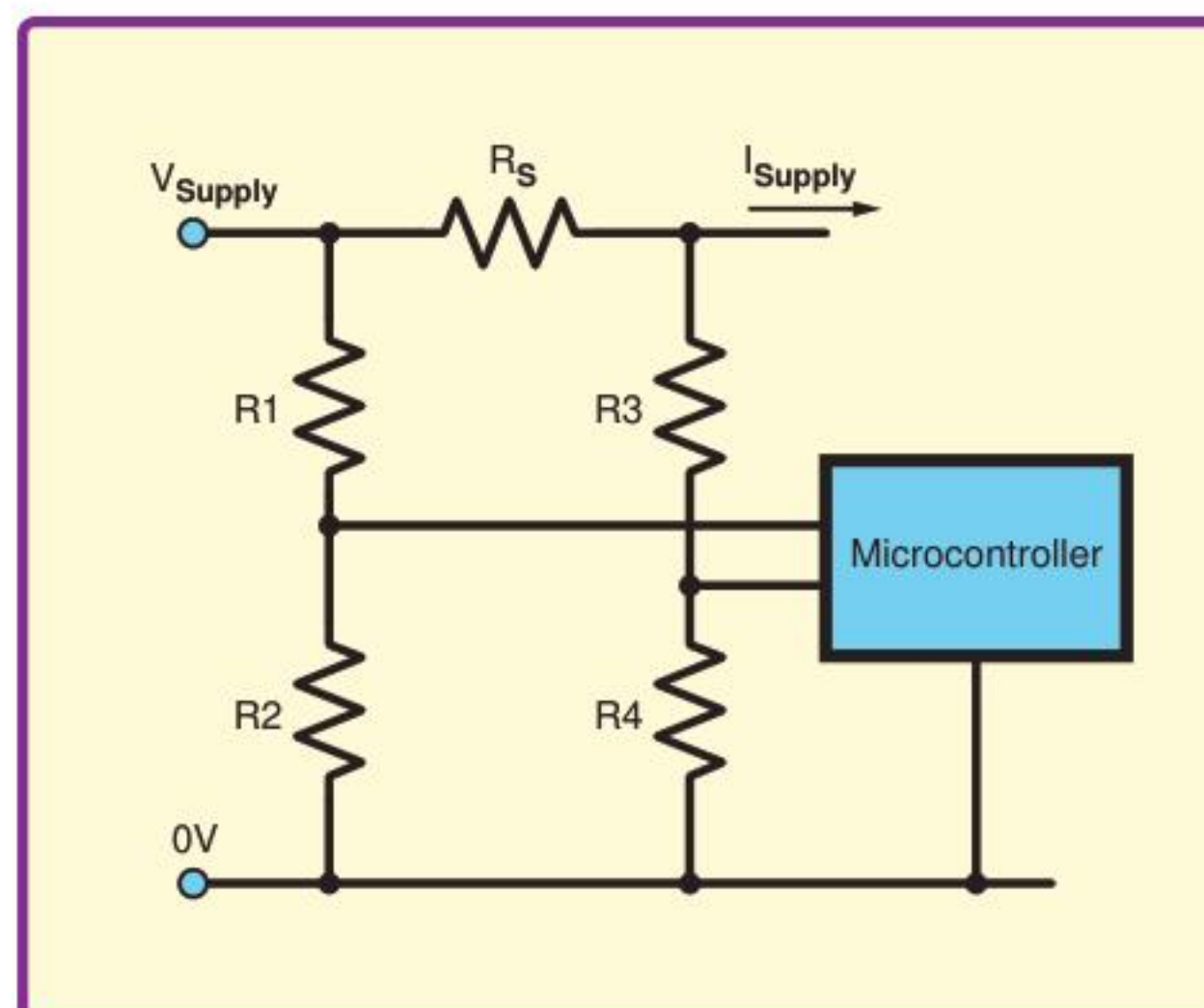


Fig.1. Traditional, current-sensing resistor measurement technique, which for my application would suffer from poor resolution

matched transistors, whose action is to sense the unipolar current in a low-value resistor at floating voltage, and send a small constant fraction of the sense current out of the third terminal (Fig.2). Ignoring R_b for the moment, the current-mirror action of matched pair Q3/Q4 forces practically the same current to flow through Q1 as through Q2, and therefore for them to have the same base-emitter voltages, so the voltage drop across R_m is forced to match the voltage drop across R_s . The voltage drop across R_s is, of course, mainly controlled by the supply current to the driven circuit I_{supply} , but also half the current contribution to I_{sense} . The voltage drop across R_m is due to the other half of I_{sense} . Thus we have:

$$R_m \times \frac{1}{2} I_{sense} = R_s \times (\frac{1}{2} I_{sense} + I_{supply})$$

Or

$$I_{sense} = I_{supply} \times 2 \times R_s / (R_m - R_s)$$

This sense current can then be converted to a ground-referenced voltage by sending it through a resistor connected to the 0V reference, and then

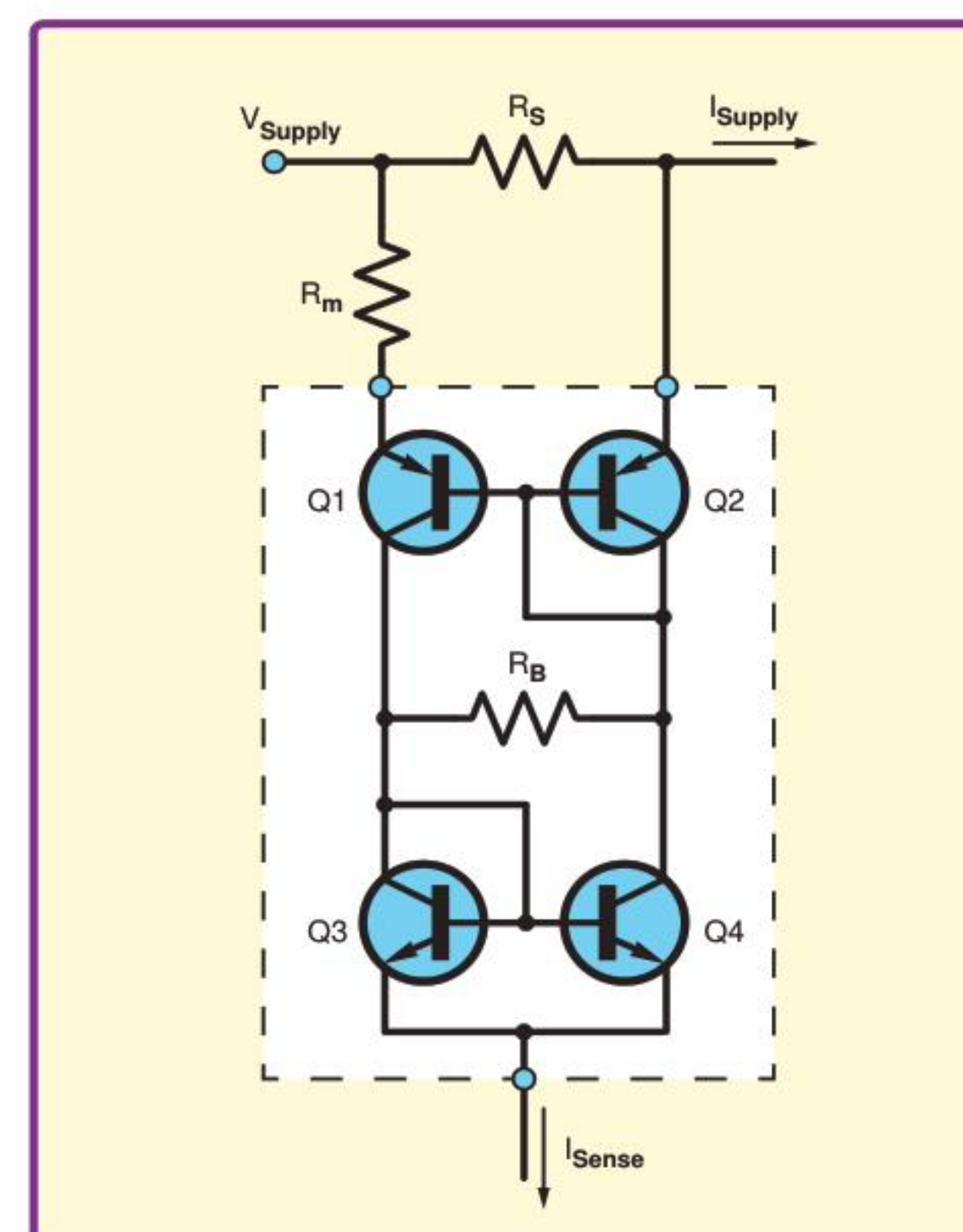
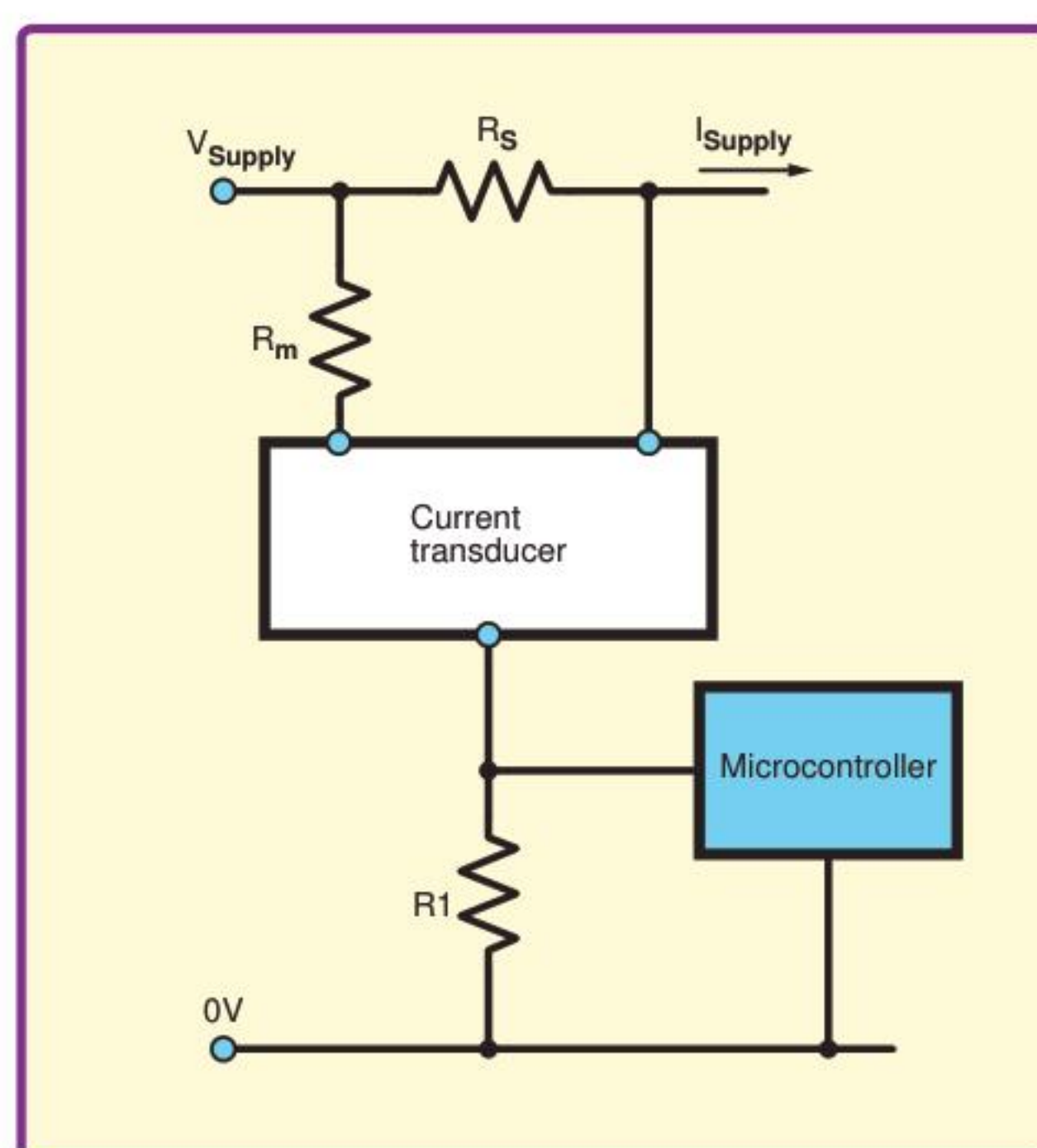


Fig.2. My unique three-terminal circuit using two pairs of matched transistors, which senses the unipolar current in a low-value resistor at floating voltage. A small constant fraction of the sense current emerges from the third terminal



measured by a single microcontroller ADC input (Fig.3) or any other voltage-driven circuit. Thus, with $R_s = 1\Omega$, $R_m = 100\Omega$, and $R1 = 1k\Omega$, the voltage output is very close to $20V/A$ of I_{supply} .

The $I_{\text{sense}}^{\text{supply}}$ terminal of the circuit is floating, so the supply voltage can be anything between a few volts above the maximum required sense output voltage to the breakdown voltage of the transistors.

I had the privilege of running my circuit past the late, great, analogue design guru a seminar. He said he ion before, and that's nal. Bob spotted a flaw start up' – if there is no rors, there is no reason n. In fact, the minimal s should be sufficient sistor R_b can be added (eg, $10M\Omega$), so that it uit too much.

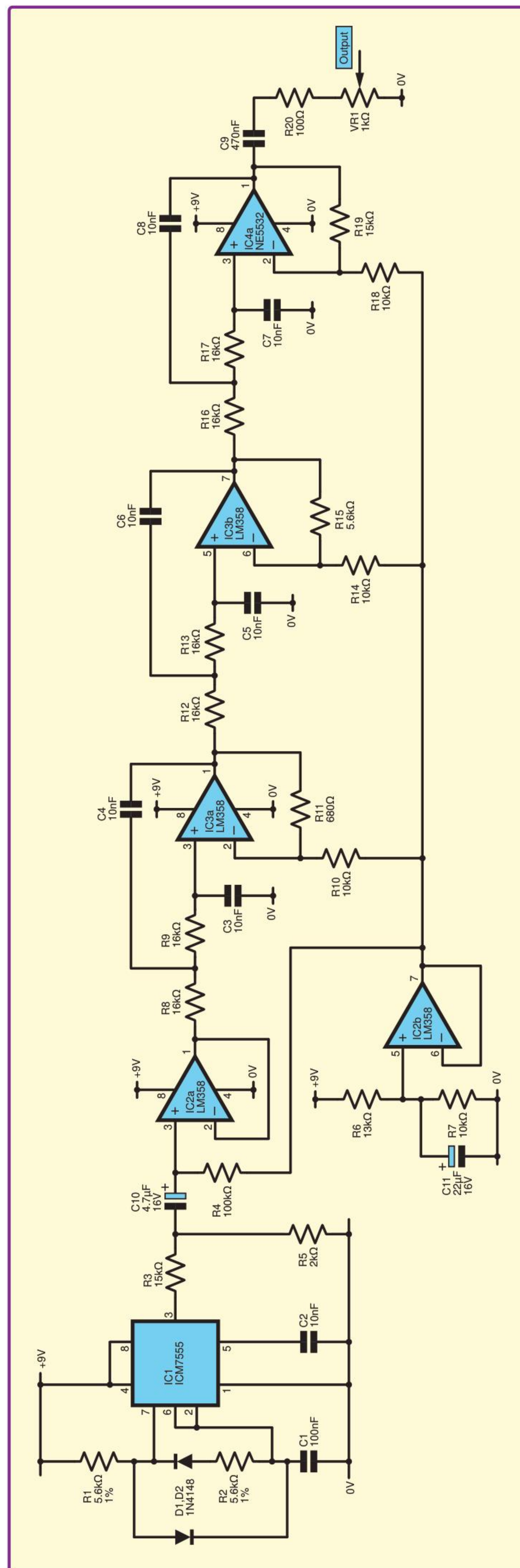
Ken Wood

Single frequency sinewave generator

I F YOU do not have access to a commercial function generator or you require the use of a simple portable signal generator then this circuit could be for you. The single frequency 1kHz (nominal) sinewave generator featured here can be used as a cheap and effective tool for testing and diagnosing faults in amplifier and speaker set-ups, or for providing a simple test signal when bread-boarding and developing audio circuitry such as amplifiers.

The circuit basically consists of an astable 555 timer followed by a low-pass filter. This design makes use of the fact that any periodic waveform can be formed by adding together a set of sinewaves of various frequencies and amplitudes. This circuit actually uses this principle in reverse, that is to say it generates a nominal 1kHz square-wave using a 7555 CMOS timer and passes the output from this timer through a low-pass filter to remove all frequencies above the fundamental frequency. A square-wave is comprised of the fundamental frequency, f plus all the odd harmonics at $3f$, $5f$, $7f$, $9f$, $11f$... *ad infinitum*, and so the filter's cut-off frequency is simply set to about 1kHz to remove these odd harmonics, leaving just the fundamental 1kHz sinewave at the circuit's output.

The 7555's circuit configuration includes two diodes, D1 and D2, which are used to enable a 50%-duty-cycle waveform to be generated. The potential divider at the 7555's output reduces the amplitude of the square wave. This is done to avoid saturating the following op amps, which have gain. This potential divider has a low enough output impedance to allow it to drive the following 100k Ω input impedance with very little signal loss.



Op amp IC2b and its associated components generate a 'mid-rail' signal ground for the filter circuitry. R6 and R7 do not have equal values. This is because the LM358, being a single supply op amp, has an output that can swing to very near the power supply ground but will, in the LM358's case, saturate at a volt or two below the positive rail. R6 and R7 therefore set the mid-rail reference at midway between these two output extremes, which provides for equal available output swing in either direction.

C10 and R4 DC shift or bias the signal up to mid-rail and op amp IC2a buffers this mid-rail square-wave signal to provide a high-impedance

input and a low-impedance output to drive the filter.

IC3a, 3b and 4a and their associated components comprise the six-pole (sixth-order) Sallen-and-Key Butterworth filter that, as mentioned, has a cut-off frequency (-3dB point) of around 1kHz. This filter, being six-pole, has an overall roll-off rate of -36dB/octave.

The three filter stages each have their gain set by the resistor feedback networks. This is a different configuration to the perhaps more commonly seen setup, where the filter op amp is connected as a buffer. These gain values are close to 1.068, 1.586 and 2.483, which are the regular

values sourced from the standard filter tables for a six-pole Butterworth response. The advantage of giving each stage some gain is that it simplifies the calculation of the filter component values which can, as a result, all be the same value, the cut-off frequency being $f_c = 1/(2\pi RC)$.

C9 couples the AC waveform, while at the same time blocking the DC voltage present at the filter's output, thereby referencing the circuit's output to power supply ground. VR1, a 1kΩ pot enables the 1kHz tone's output amplitude to be set to the required level

Chris Hinchcliffe, Dorset

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Max's Hot Beans

By Max The Magnificent

I've been Obducted and I love it!

In my previous column I mentioned that, way back in the mists of time we call 2013, I supported a Kickstarter project for a game called Obduction. Created by the folks at Cyan, Obduction is billed as being the spiritual descendant of the legendary Myst and Riven games.

Well, there's good news and not-so-good news. The good news is that the PC incarnation of Obduction is now available. The not-so-good news is that at the time of writing this, the virtual reality (VR) version is yet to make an appearance (the folks at Cyan say that they are just adding the final touches and that it will be here soon).

In the meantime, I've had a little problem. The honking-big VR workstation I had built – boasting a 6th generation quad-core, hyper-threaded, water-cooled Intel Core i7 processor running at 4GHz with 16GB RAM, coupled with an Nvidia GeForce GTX 1070 with 8GB of GDDR5 memory – was only ever intended to drive my Oculus Rift headset. Thus, I didn't bother equipping it with speakers (the Oculus has built-in headphones) and I slapped on the smallest of monitors, whose sole purpose was to perform housekeeping tasks.

As you can imagine, it was sort of embarrassing to have the PC version of Obduction and still not have a platform upon which I could play it. Thus, I immediately went online and purchased a set of Creative Reference Multimedia Monitors from Amazon for \$99 (<http://amzn.to/2bIUxxq>). I then raced over to see my chum Daniel, who works at GigaParts.com where, on his recommendation, I acquired an Acer 34-inch UltraWide curved monitor with an aspect ratio of 21:9, but I'm not going to tell you how much that cost; suffice it to say that I still have tears in my eyes. (I'm sorry for specifying prices in US dollars and giving American URLs, but remember that this is where I hang my hat these days).

This new monitor supports a resolution of 3440×1440 , which is higher than I can count. Fortunately, Obduction also supports this, as does my GTX 1070 graphics card. All I can say is that the result is jaw-dropping. The clouds drifting across the sky are realistic, as is the water in the rivers and lakes. The grasses, flowers and trees move gently in the breeze, as do their shadows. Every building, object, and rock is sumptuously rendered. The Obduction universe is as weird and wonderful as I could ever have dreamed. On the standard brain-boggling scale

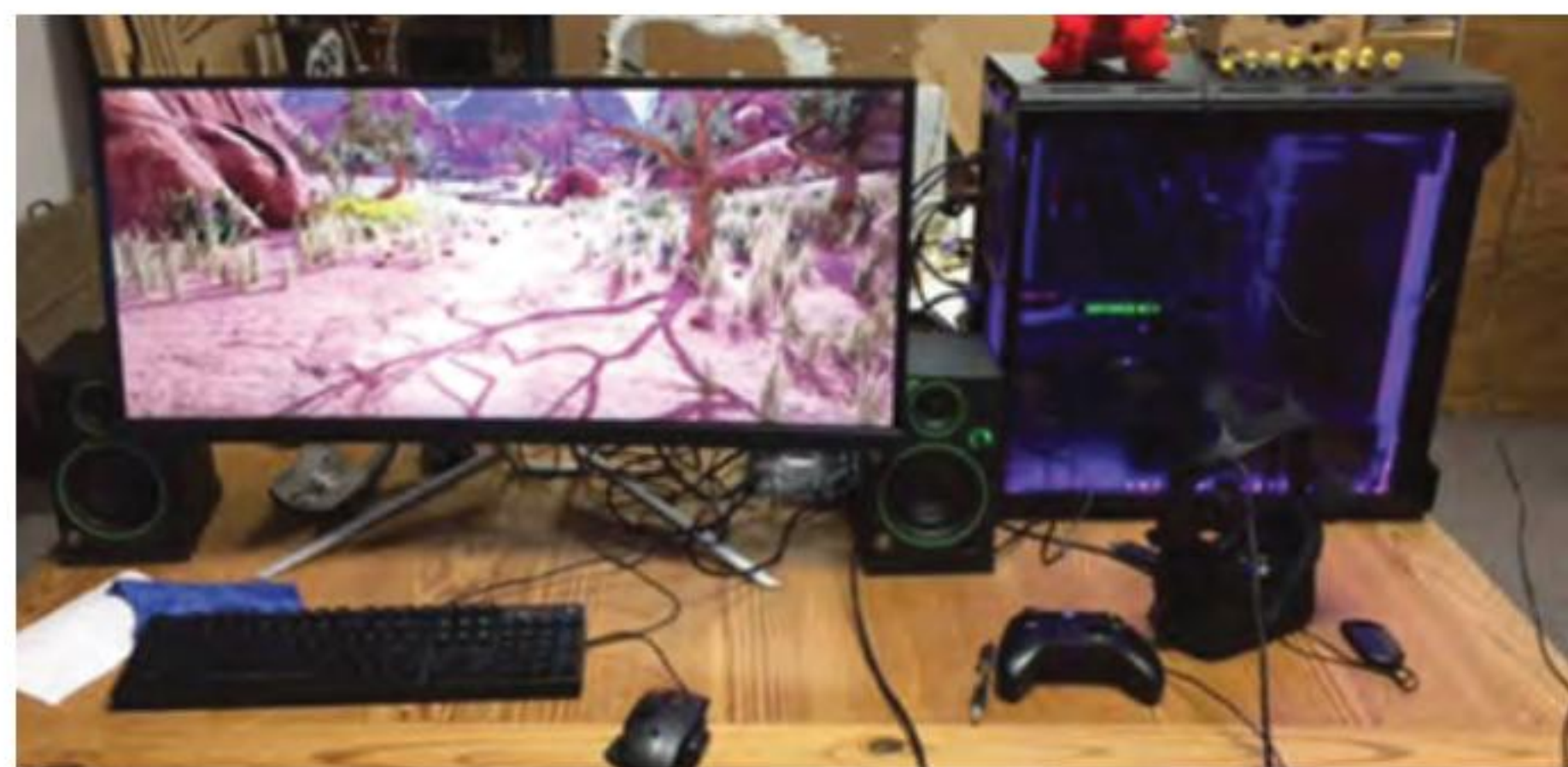


Fig.1. Max's new monitor and speakers



Fig.2. Flat-packed VR via Google Cardboard – before and after assembly

of 1 to 10 (as defined by the American Medical Association), my brain has been boggled to at least an 11 (quite possibly a 12), and this is only the 2D PC version – I cannot even imagine what the VR implementation is going to be like!

Dipping one's toes in the VR waters

In my opinion, 2016 is going to be regarded as a 'break-point' year for virtual reality. The floodgates have been opened and we are going to be inundated with virtual reality (and augmented reality) headsets and applications. So, if you are thinking about dipping your own toes in the virtual reality waters, where should you start?

If you are looking for cheap-and-cheerful, then you need look no further than Google Cardboard (<http://bit.ly/1LWsIIk>), which actually made its debut way back in 2014. Basically, this is a cardboard box with two lenses, into which you insert the smartphone of your choice. There are several different flavours of this, but you can pick up a nice version for as little as \$12 on Amazon (<http://amzn.to/2ckcjTK>). The advantages are that it's cheap and it works with both Android and iOS (Apple) phones; also, there are a lot of free VR apps for it on the Internet. The disadvantages are that it's really uncomfortable, you can't adjust the focus or the distance between



Fig.3. Comparison of Gear VR (left) vs VR Box, front and back

the lenses, and the apps are only as good as they can be considering the display technology you are using. But hey, for 12 bucks it is still pretty good!

Moving up the ladder, we have the Gear VR, which used to be \$99, but which you can purchase for as little as \$60 on Amazon these days (<http://amzn.to/2bWdeJ6>). The main disadvantage of the Gear VR is that it only works with Samsung phones. Contrawise, the corresponding advantage is that when you insert your phone, it plugs into and becomes tightly integrated with the headset. Another disadvantage is that you can only access Gear VR content from the Oculus Store, but the corresponding advantage is that this content is of good quality – as good as you can expect considering you are using a smartphone to perform your computation and graphics processing. I also like the fact that the Gear VR has integrated control, plus you can modify the focus (but not the distance between the lenses).

If you are short of money and/or don't have a Samsung smartphone, there is a very tasty option called the VR Box. Once again, there are a number of suppliers for this little rascal, but you can pick one up for as little as ~\$10 from Amazon (<http://amzn.to/2bWeAmQ>) (for a few dollars more you can get one with a small Bluetooth controller). In addition to the fact that the VR Box works with pretty much any Android or iOS phone (up to the size of an iPhone 6 Plus), it also allows you to change both the focus on an eye-by-eye basis and the distance between the lenses. You also have access to a wide range of cheap-

and-cheerful VR content on the Internet, but – once again – you are limited by the fact that you are using a smartphone to perform your number and graphics crunching.

Taking a deeper plunge

There are two platforms that currently hold the high ground in commercial VR space – the Oculus Rift, which costs around \$600 (<http://ocul.us/29N3geD>), and the HTC Vive, which costs about \$800 (<http://bit.ly/1ZOZzGR>). Note that you'll also need a honking big processor and graphics card to drive these little beauties – you can expect to pay anything from \$1,500 to \$5,000 (professional gamers pay \$10,000 and up for their machines).

Putting one of these headsets on is as close as you can imagine to being on a Star Trek holodeck. But be warned – once you've tried one of these bad boys, you will *never* be satisfied with one of their smartphone-based cousins. In my next column, we'll look at the Oculus Rift and HTC Vive in more detail. Until then, have a good one!



Fig.4. Max in a (VR) world of his own using the Oculus Rift and the non-negotiable Hawaiian shirt

Any comments or questions? – please feel free to send me an email at: max@CliveMaxfield.com



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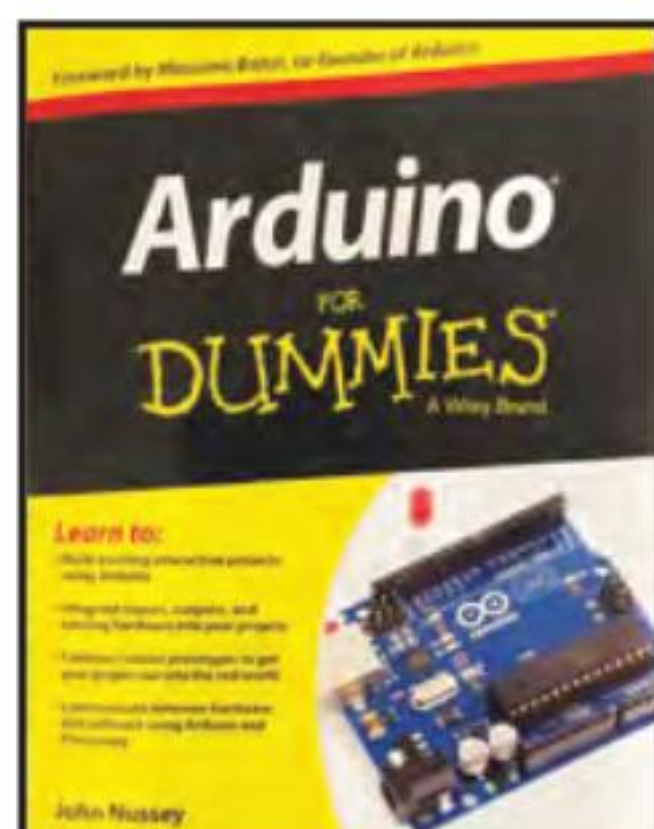
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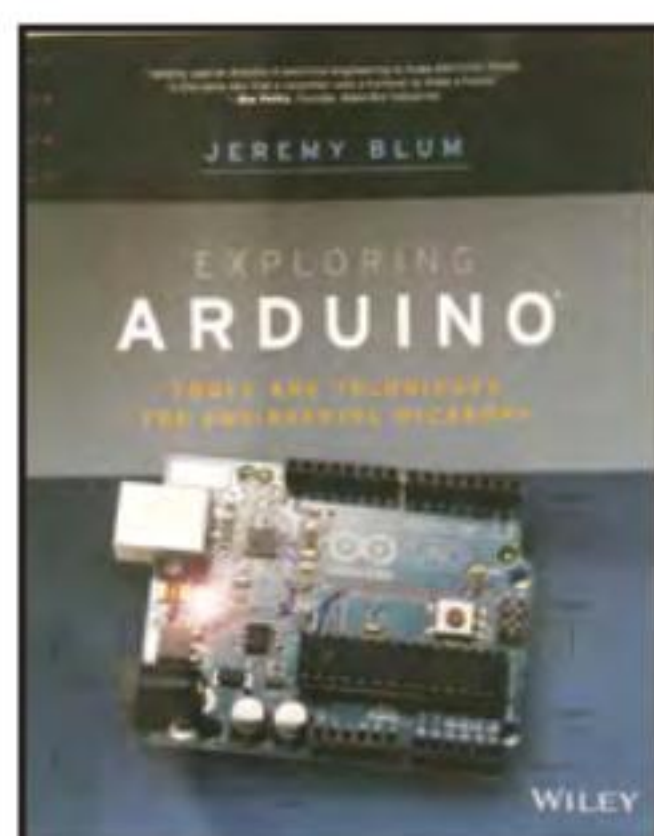
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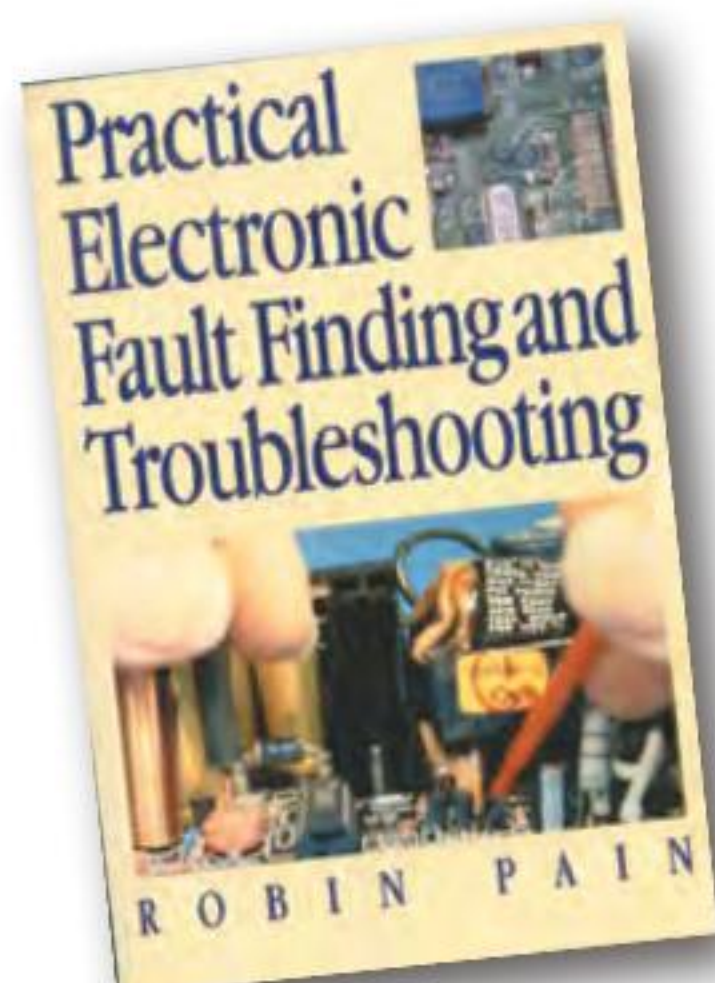
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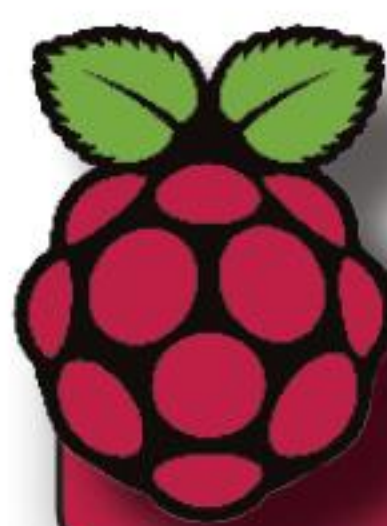
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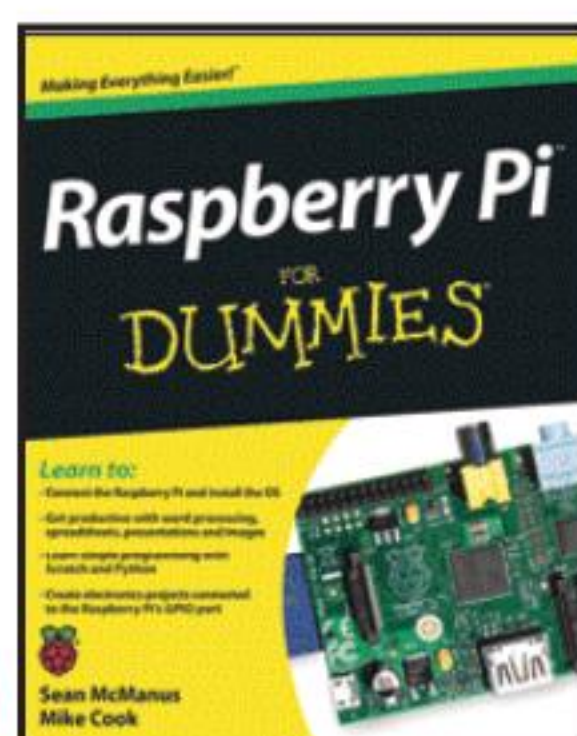


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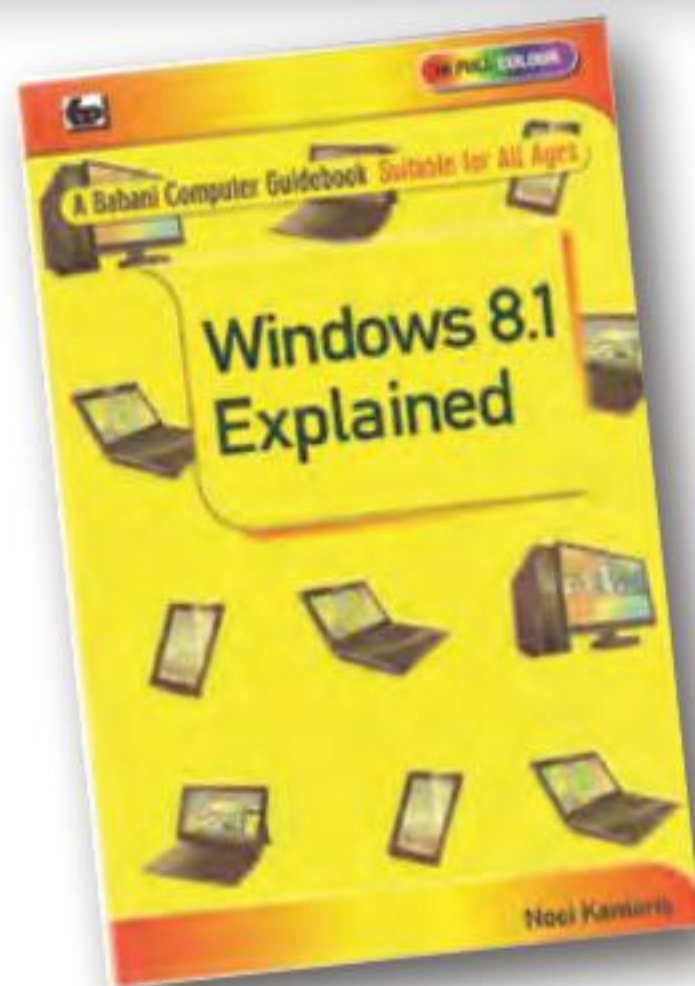
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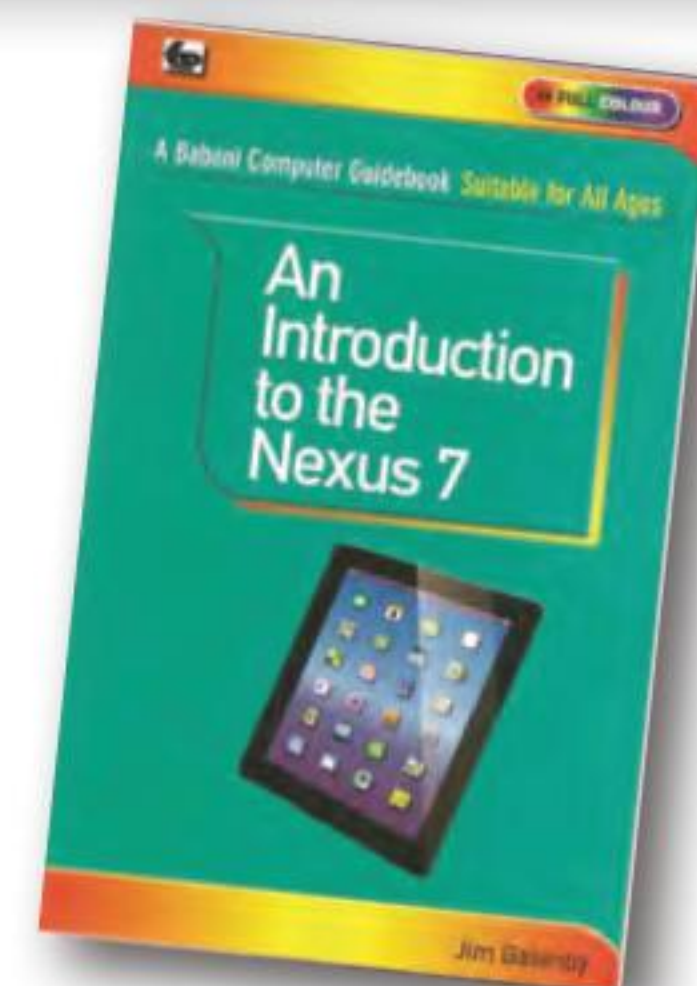
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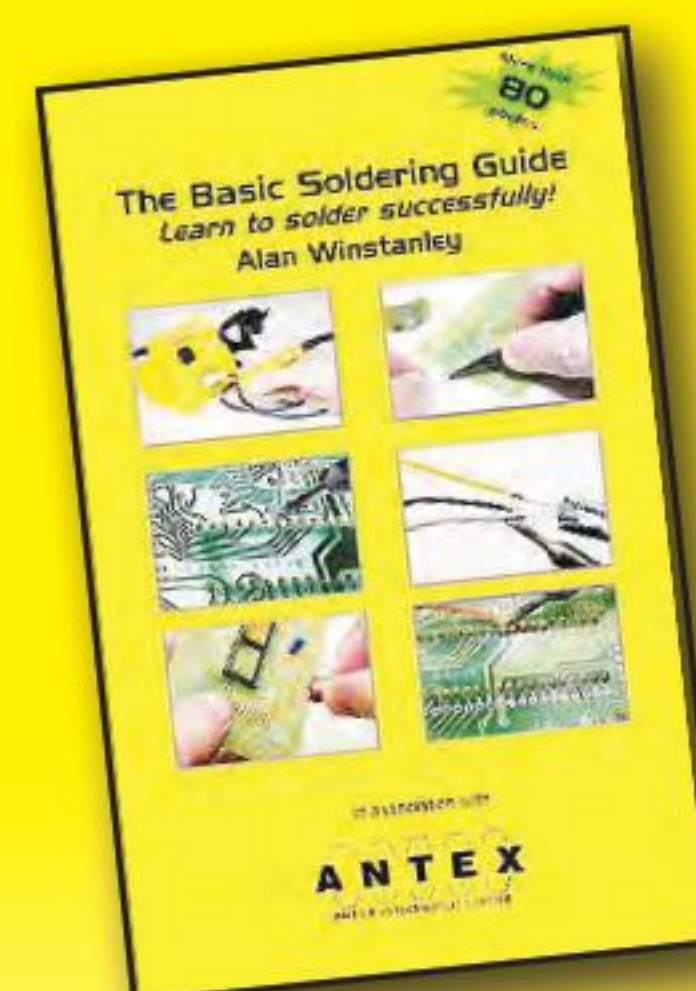
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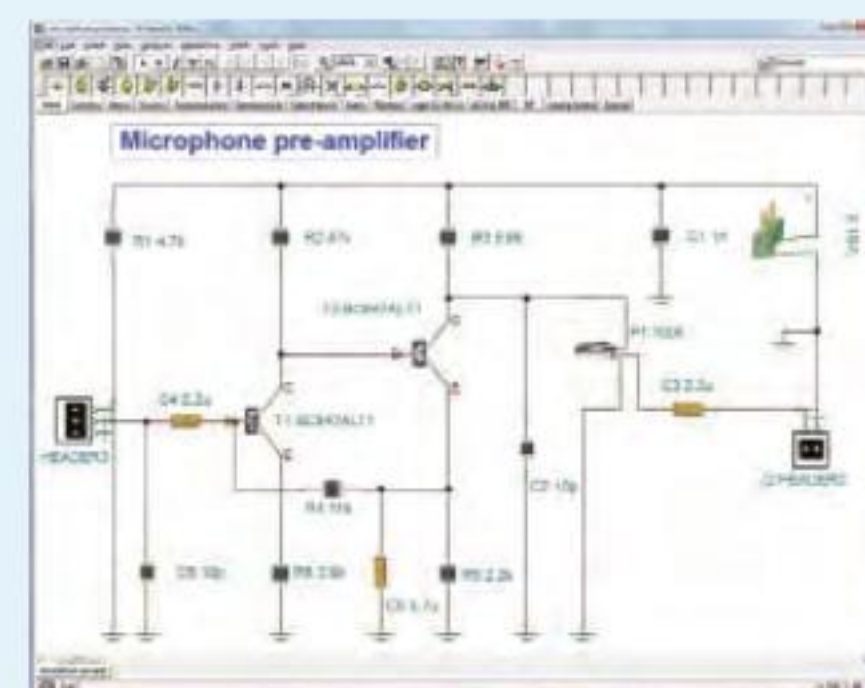
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The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

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The CD-ROM also contains all of the software for the Teach-In 2 series and PIC N' Mix articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

CD-ROM Order code ETI2 CD-ROM £9.50

ELECTRONICS TEACH-IN 3

ELECTRONICS TEACH-IN 3 CD-ROM

The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to Circuit Surgery, the regular EPE clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – Practically Speaking – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and identifying components, are covered. Finally, our collection of Ingenuity Unlimited circuits provides over 40 circuit designs submitted by the readers of EPE.

The CD-ROM also contains the complete Electronics Teach-In 1 book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

CD-ROM Order code ETI3 CD-ROM £8.50

ELECTRONICS TEACH-IN 4

ELECTRONICS TEACH-IN 4 CD-ROM

A Broad-Based Introduction to Electronics.

The Teach-In 4 CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The CD-ROM also contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

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PICmicro TUTORIALS AND PROGRAMMING

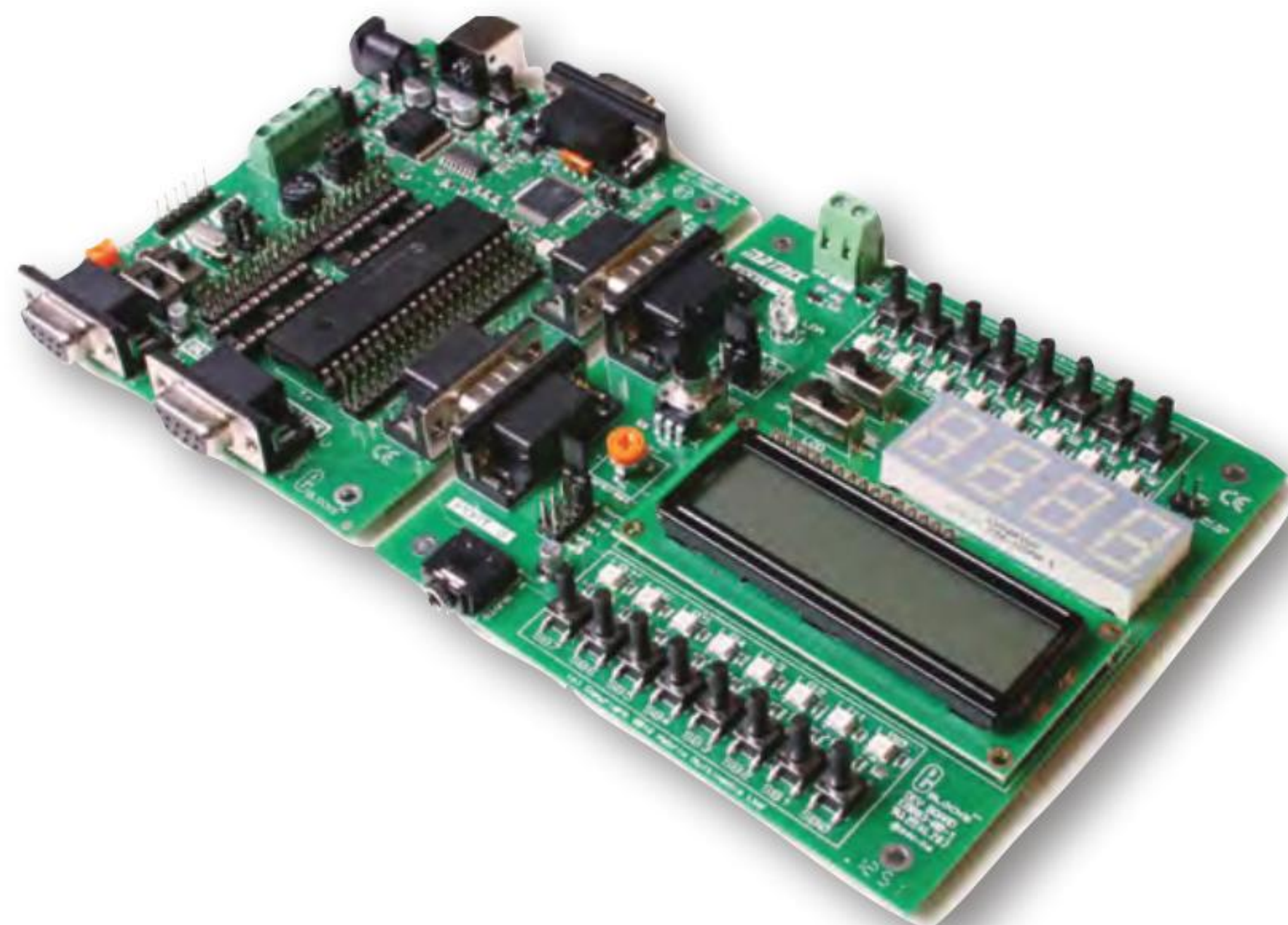
HARDWARE

PICmicro Multiprogrammer Board and Development Board

Suitable for use with the three software packages listed below

This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the MLoader utility that is free to download when you buy the multiprogrammer board. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
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- Compatible with the E-blocks range of accessories



£167 including VAT and postage, supplied with USB cable and free to download programming software

SOFTWARE

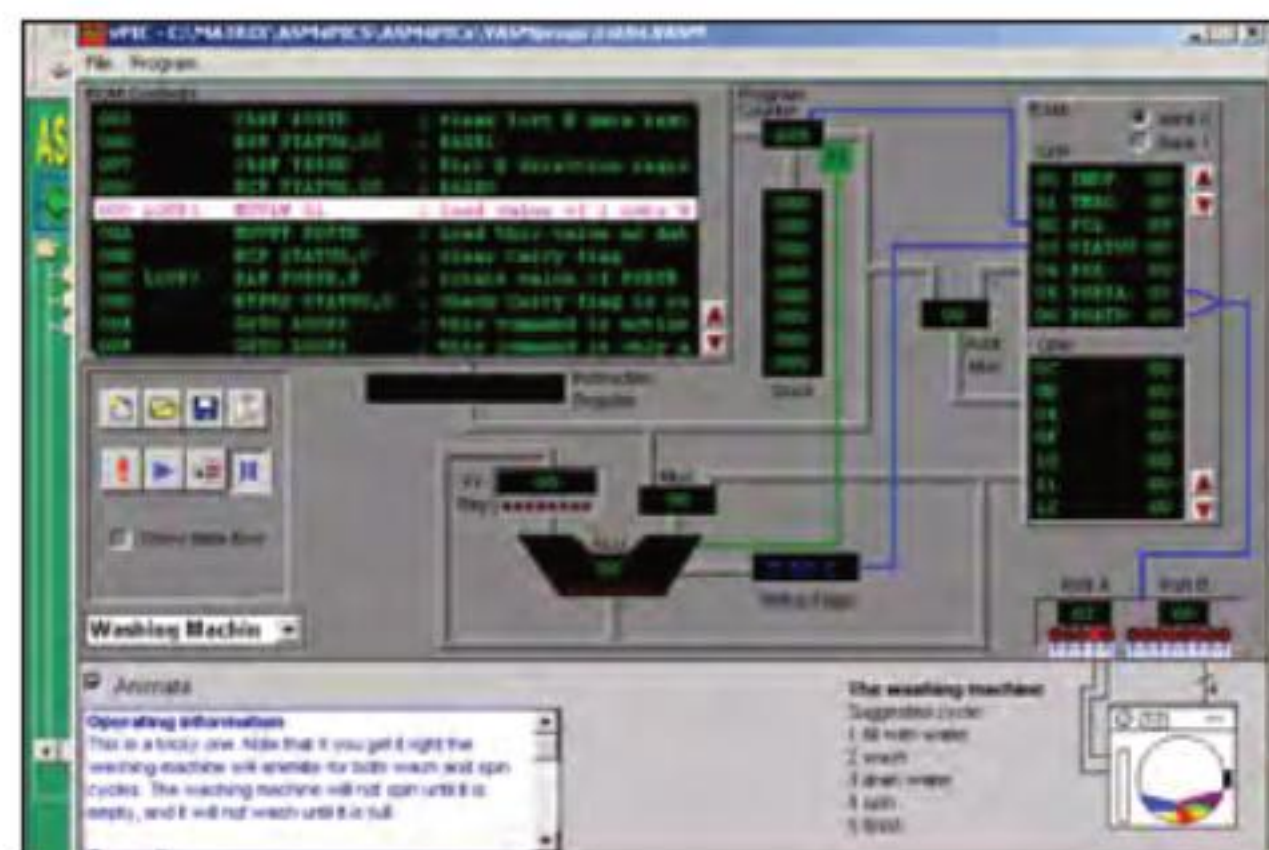
ASSEMBLY FOR PICmicro V5

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

- Comprehensive instruction through 45 tutorial sections
- Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator
- Tests, exercises and projects covering a wide range of PICmicro MCU applications
- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture and functions
- Expert system for code entry helps first time users
- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
- Imports MPASM files.

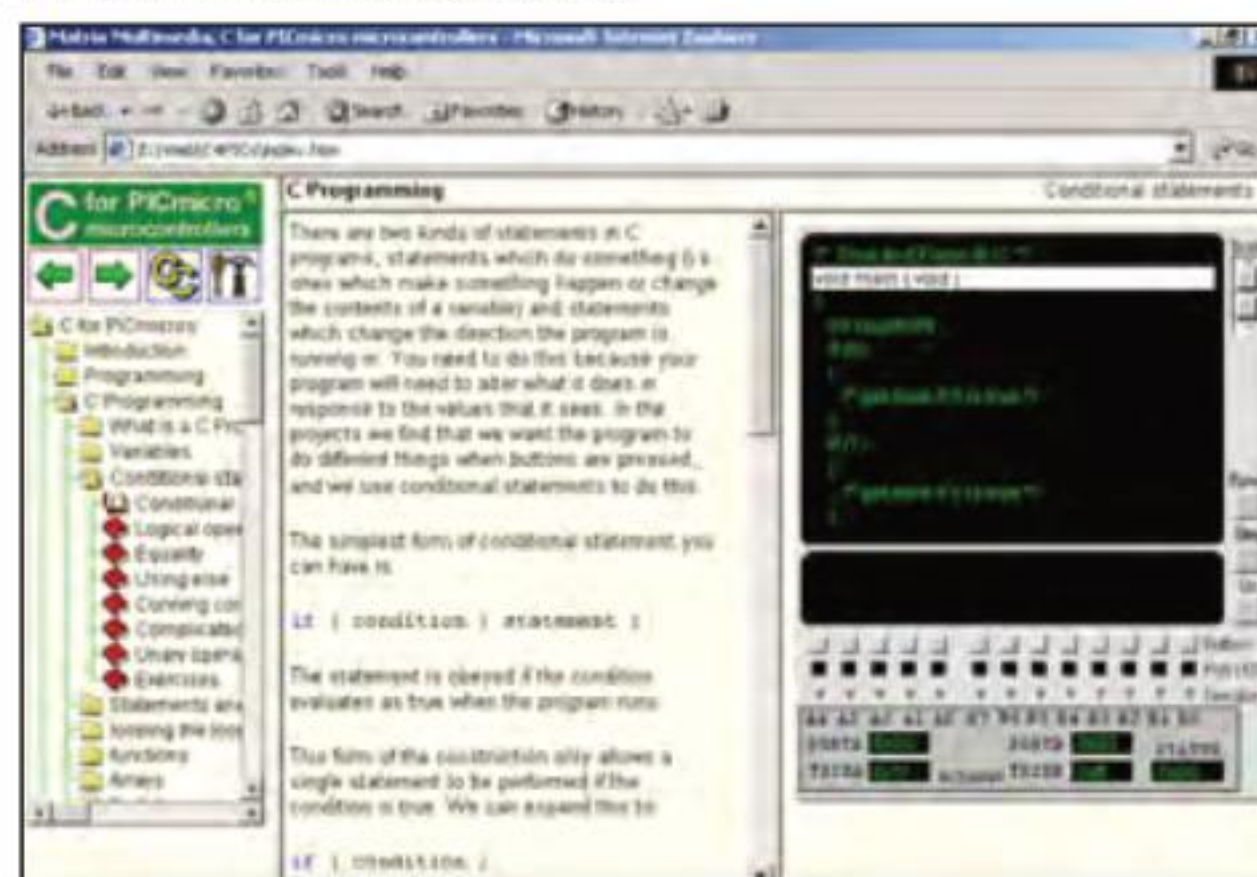


'C' FOR 16 Series PICmicro Version 5

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

- Complete course in C as well as C programming for PICmicro microcontrollers
- Highly interactive course
- Virtual C PICmicro improves understanding
- Includes a C compiler for a wide range of PICmicro devices
- Includes full Integrated Development Environment
- Includes MPLAB software
- Compatible with most PICmicro programmers
- Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

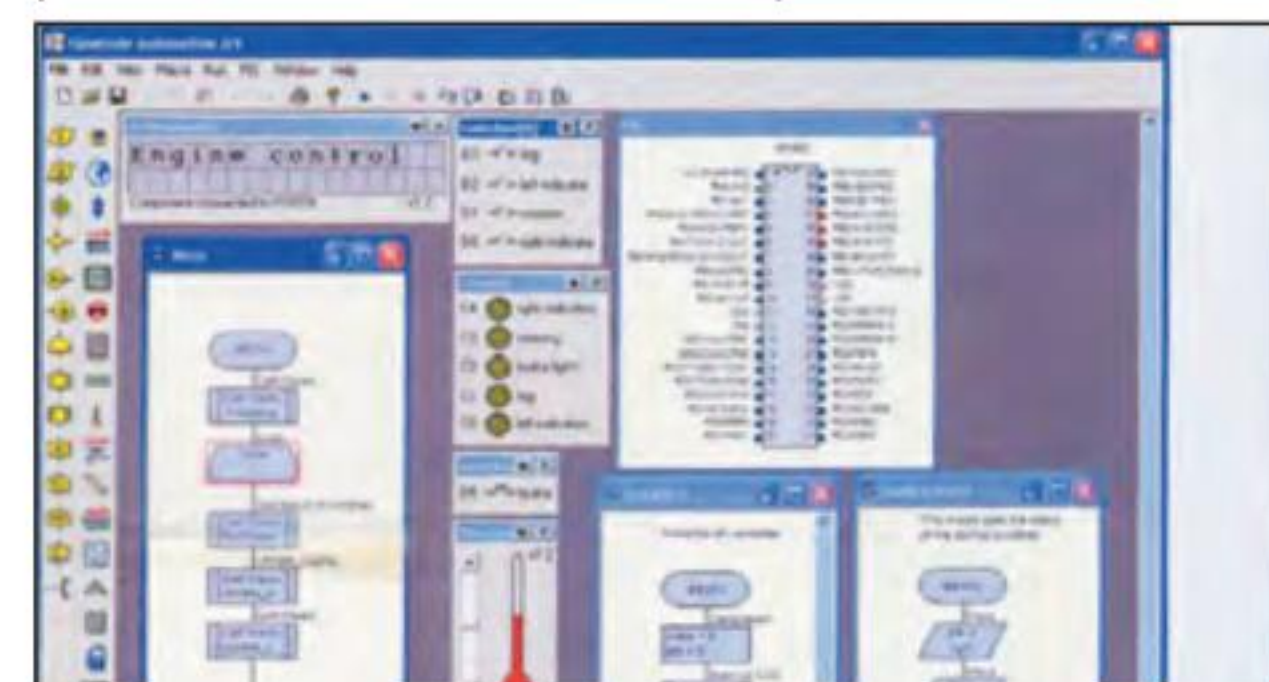
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Please note: Due to popular demand, Flowcode PICmicro, AVR, DSPIC, PIC24 & ARM V6 are now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you. If you require the CDROM as a back-up then please add an extra £14 to the price.



PRICES

Prices for each of the CD-ROMs above are:
(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	£58.80	inc VAT
Professional (Schools/HE/FE/Industry)	£150	plus VAT
Professional 10 user (Network Licence)	£499	plus VAT
Site Licence	£999	plus VAT

Flowcode (choose PIC, AVR, ARM, dsPIC, PIC24) . . . £94.80 plus VAT

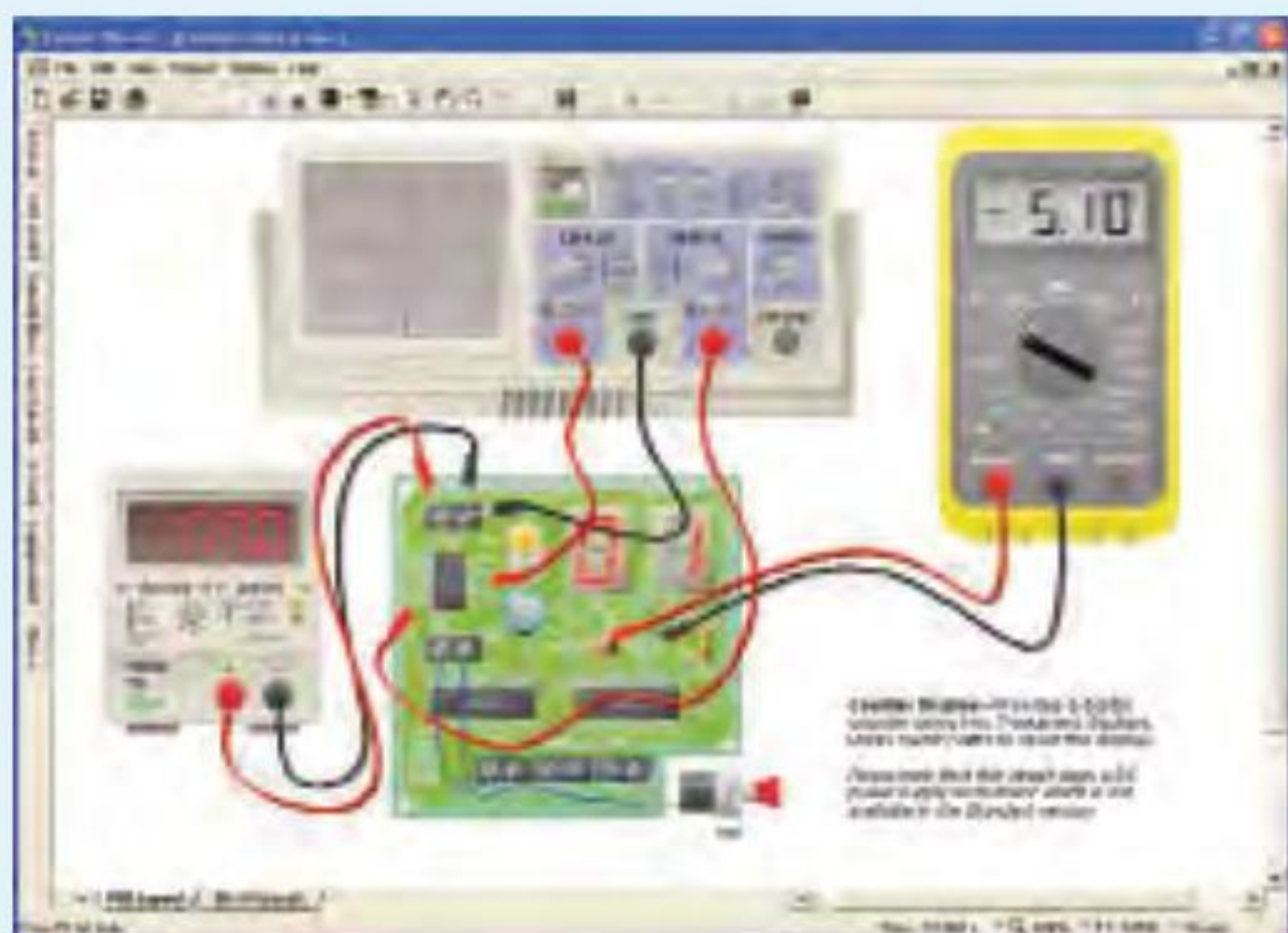
CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

- * Circuit diagram design with component library (500 components Standard, 1500 components Professional)
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- * Interactive circuit diagram simulation
- * True analogue/digital simulation
- * Simulation of component destruction
- * PCB Layout
- * Interactive PCB layout simulation
- * Automatic PCB routing
- * Gerber export
- * Multi-level zoom (25% to 1000%)
- * Multiple undo and redo
- * Copy and paste to other software
- * Multiple document support



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard £61.25 inc. VAT. Professional £75 plus VAT.

GCSE ELECTRONICS

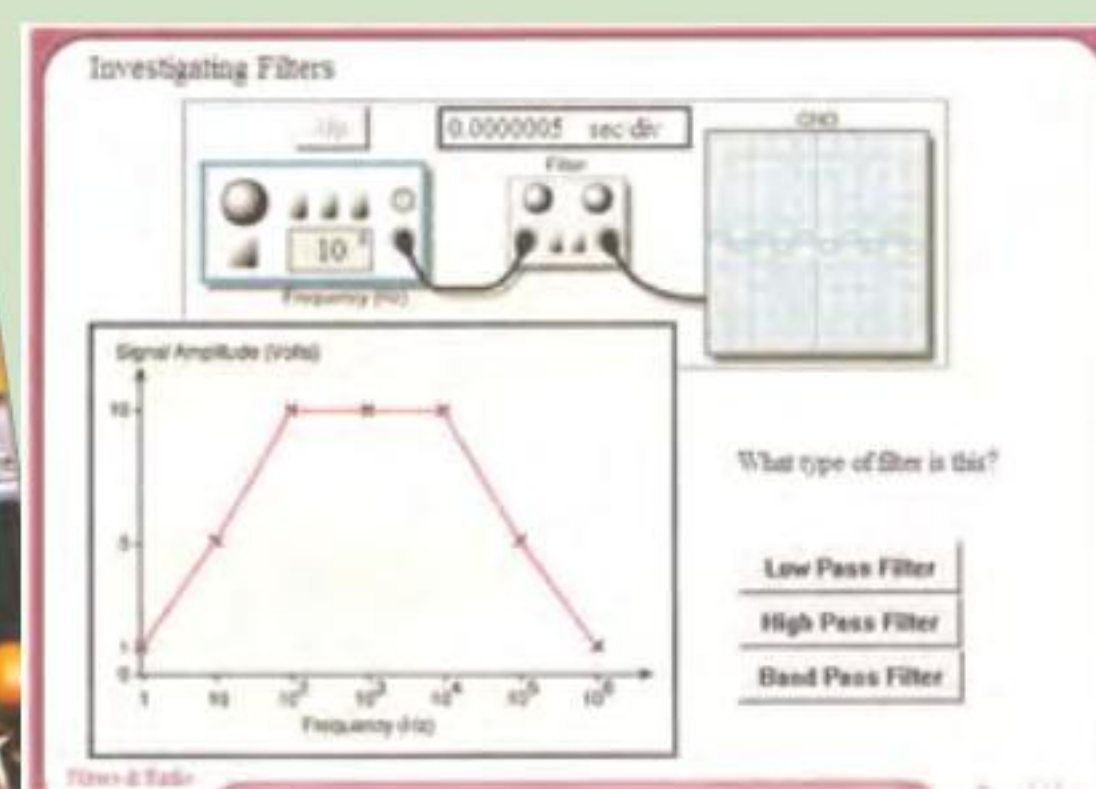
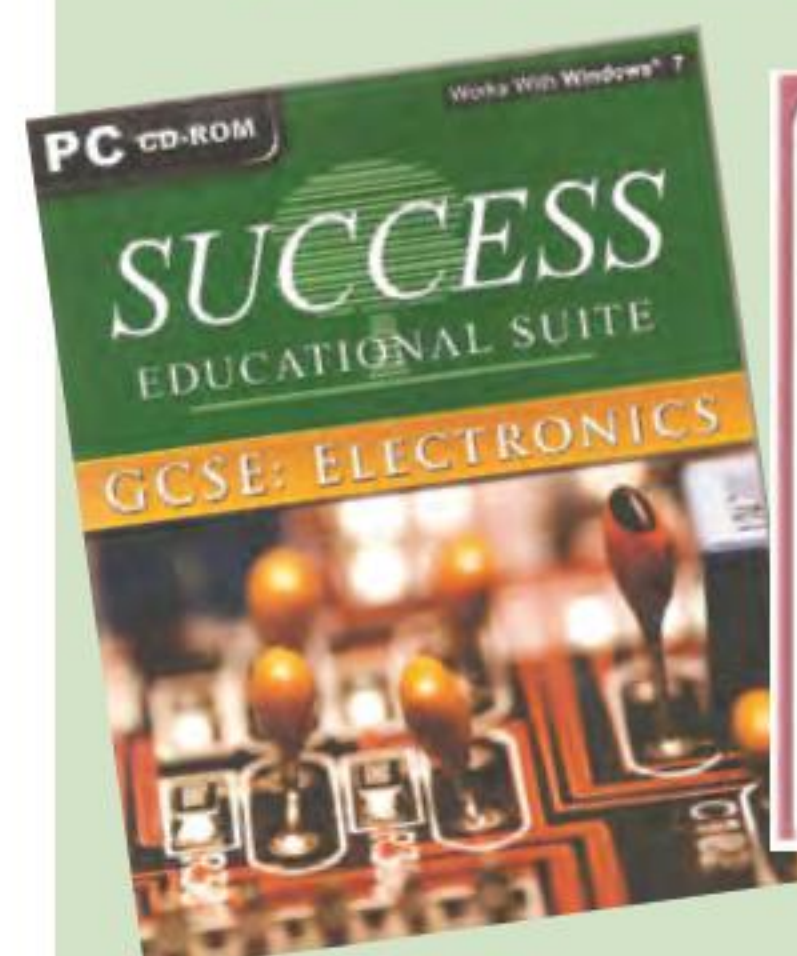
Suitable for any student who is serious about studying and who wants to achieve the best grade possible. Each program's clear, patient and structured delivery will aid understanding of electronics and assist in developing a confident approach to answering GCSE questions. The CD-ROM will be invaluable to anyone studying electronics, not just GCSE students.

- * Contains comprehensive teaching material to cover the National Curriculum syllabus
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Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

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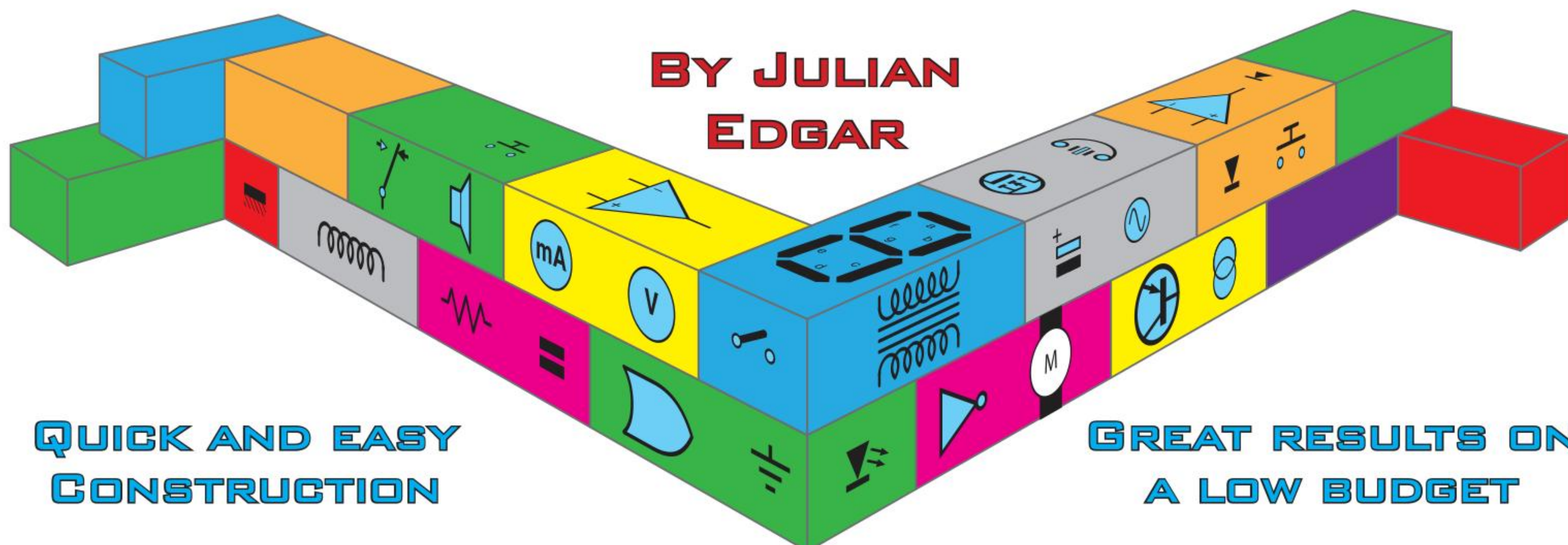
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VARIABLE FREQUENCY MODULE

Large complex projects are fun, but they take time and can be expensive. Sometimes you just want a quick result at low cost. That's where this series of *Electronic Building Blocks* fits in. We use 'cheap as chips' components bought online to get you where you want to be... FAST! These projects range from around £15 to under a fiver... bargains!

Here's a building block that is great for alarms and security indicators. Remember when you wanted to have an LED flasher, so you built a circuit from scratch with a handful of components? And then when you wanted to change the frequency or duty cycle of the circuit, you needed to make component changes? And – for me at least – it always took ages to get the result that was wanted.

Well, now all that has changed. For less than the price you would have once paid for the simple flasher's components, you can now get a pre-built module that has adjustable frequency, adjustable duty cycle – and can directly drive loads like high intensity LEDs and piezo buzzers. And that price includes delivery to your letterbox.

How much then? This module costs less than £2, including postage! So what do you get for your money? The very small PCB, just 35 × 37mm, doesn't feature the IC you might expect – our old friend the venerable 555. Instead, it uses an LM358 op amp. This in turn drives an S9012 transistor, good for 500mA (more on this in a moment).

Adjustability range

The output frequency range is adjustable from one output per 15 seconds right through to a measured 2.2kHz. This adjustability is achieved by the

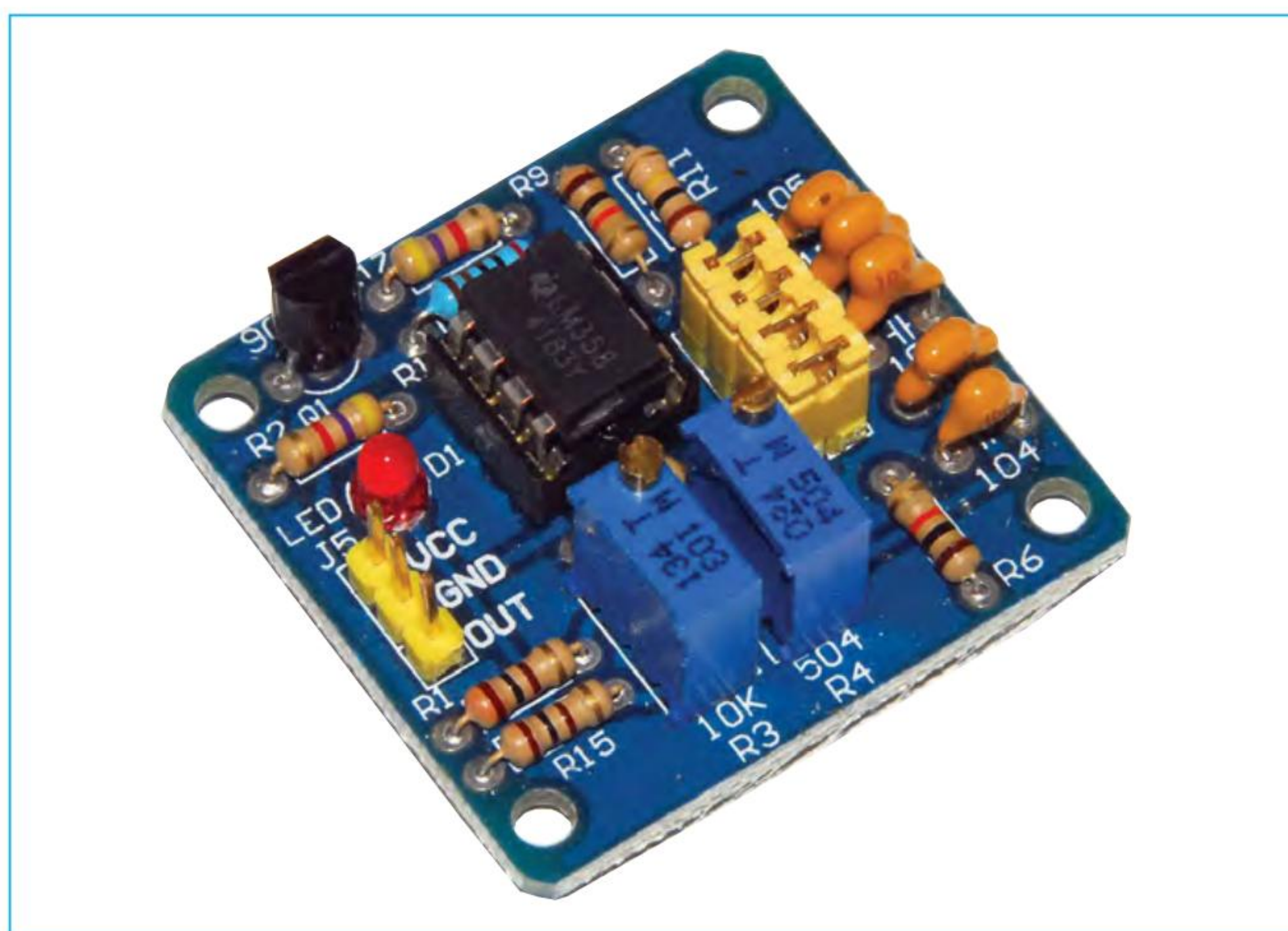


Fig.1. This Variable Frequency Module can drive real loads like high-intensity LEDs and piezo buzzers. Plus, it has variable frequency and duty cycle controls. It will work from 3 to 12V.

use of a multi-turn pot, and links (Fig.2) that are inserted or removed, depending on the frequency range required. The more links you place, the higher the output frequency. The board's other pot adjusts duty cycle – the proportion of time the output signal is on. This pot is adjustable to give a range from 0 to 100 per cent.

Pot identification

With the board oriented so that the pots are on the left, the frequency pot is the lower one. Turn it clockwise to increase frequency. The upper pot is the duty cycle control; turn it clockwise to reduce duty cycle.

Output

Now, if you're expecting a great-looking square wave at all frequencies and

duty cycles, think again! Put a scope on it and the output can get ugly at low duty cycles, high frequencies – and

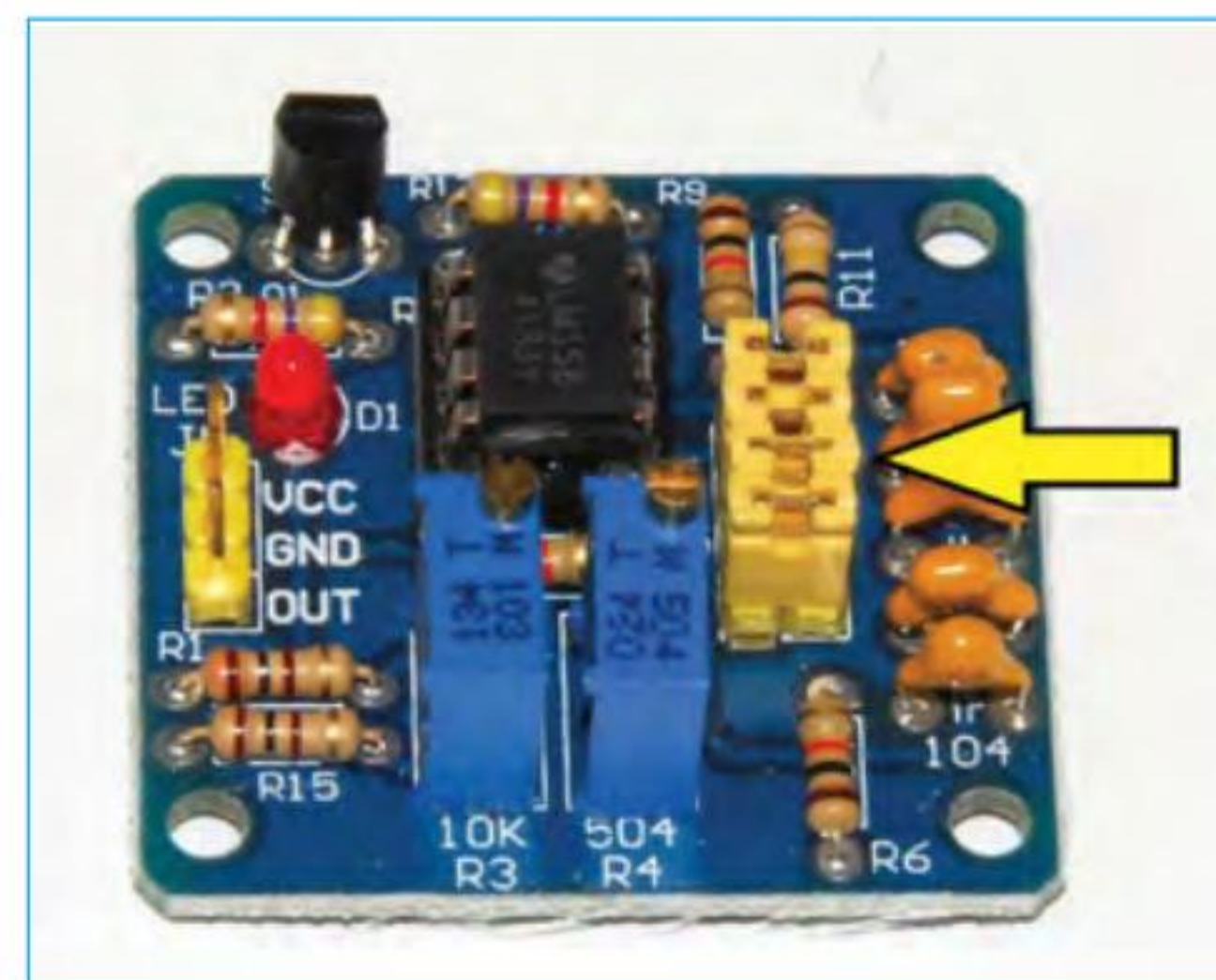


Fig.2. The frequency range is selected by adding or removing these links. The range is selectable from one output per 15 seconds, right through to 2.2kHz. Fine-tuning is then done with a pot.



Fig.3. This is the output transistor. It is suggested that it's good for 500mA, but if you are driving heavy duty loads, keep a close eye on its temperature rise.

pretty well everything in between. But, after all, it's not meant to be a precision digital frequency generator.

Loads

What it does do well is flash LEDs, pulse buzzers and perform similar functions. For example, pulse a high intensity LED and piezo buzzer at 25Hz and no-one would overlook such a warning alarm! You can also set the duty cycle to be very short (eg, 20 per cent) and the frequency very low (eg, one output per two seconds)

and in so doing, gain a very low current flasher.

A red LED is mounted on the board, and this flashes to show the output behaviour that has been selected. If absolute minimum current draw is needed, this LED could be removed. Even with it present, with no output being driven, average current draw was about 6mA with a 9V battery powering the module. Interestingly, when powering the high-intensity LED and piezo buzzer, the low duty cycle being used meant that current draw only went up to about 12mA – a very low current demand for such an attention seeker.

For high input impedance loads, the module could also be used as a signal injector at (say) 2kHz.

Currents and supply voltage

I tried the module flashing a 12V, 5W LED and the output transistor (Fig.3) started getting rather warm – and that was with a duty cycle of only about 20 per cent. So take care if you are driving larger loads.

While at least one eBay listing suggests that the module could drive relays, I could see no diode protection on the board to guard against spikes coming back from the relay coil, so I'd be a bit wary of doing this without adding an external diode.

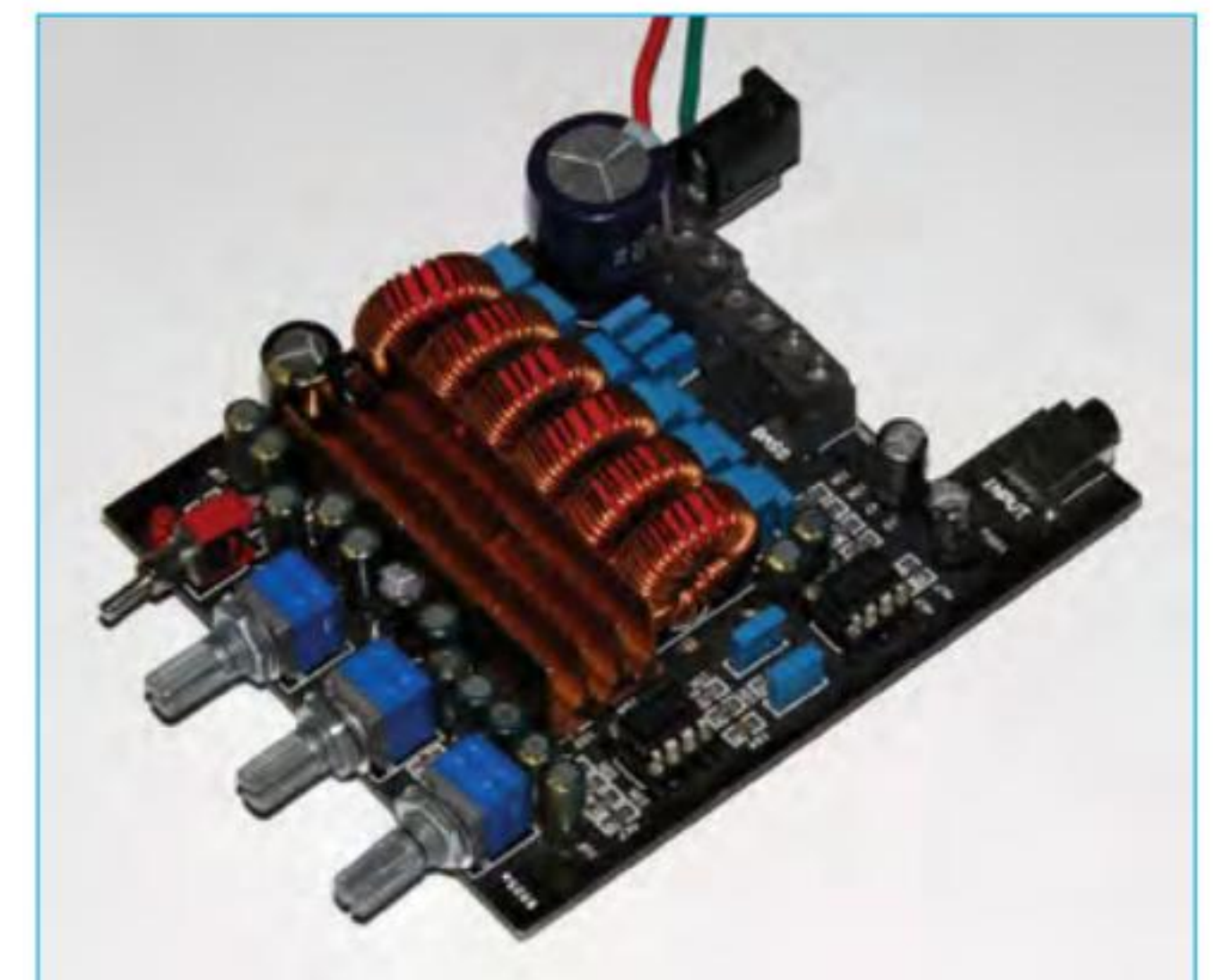
My board worked down to just 3.0V and the specs suggest that the upper range is 12.0V. The output amplitude is similar to the power voltage, so when driving LEDs, keep in mind the necessity for a suitable dropping resistor. In my testing, I used a 12V piezo buzzer and LED pre-wired with a resistor for 12V – a simple and effective combination.

Sourcing

This item is available from eBay, search for 'LM358 Duty And Frequency Square Wave' or item number 271969945647.

Next month

In December's issue we will look at a *Good Quality 2.1 Amplifier Module* for under a tenner! So you definitely do not want to miss the next super *Electronic Building Block* article!



Check out our website:
www.epemag.com

VGA Video Converter kit

As Seen in EPE Mag Jan / Feb '16

Enables the use of VGA monitors with older computers.

Digital mode converts true CGA digital input (RGB + Intensity) and outputs the proper CGA color map. Useful for : IBM PC's (CGA), Various Microbee models, C128, Tandy 1000 and more. Includes 'C128FIX' jumper to adapt the normal CGA color set to match the Commodore 128's 80 column mode color set (dark yellow of the CGA set is brown in the C128). Analogue mode supports machines such as the Amiga & Apple IIs that have true analogue RGB outputs. (Works Brilliantly on Amiga!)

Full kit, and short forms available. Cable kits also available to suit Commodore Amiga & Tandy CoCo3. This kit requires a source of 8 to 12vdc, or 5vdc at approx 1.2 amps.

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Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevant project articles.

All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com.** Cheques should be crossed and made payable to *Everyday Practical Electronics* (Payment in £ sterling only).

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

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AUG '15		
Nirvana Valve Simulator – Main PCB	01106141	£15.05
– Front Panel	01106142	£8.30
TempMasterMK3	21108141	£12.00
Teach-In 2015 – Part 7	908	£8.75
SEPT '15		
Opto-Theremin – Part 1		
– Main Theremin	23108141	£14.25
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Mini-D Stereo 10W/Channel Class-D Audio Amplifier	01110141	£7.45
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– Screening PCB	04107142	
OCT '15		
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* See NOTE left regarding PCBs with eight digit codes *

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.
Boards can only be supplied on a payment with order basis.

EPE SOFTWARE

Where available, software programs for *EPE* Projects can be downloaded free from the Library on our website, accessible via our home page at:
www.epemag.com

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards are available in PDF format free to subscribers – email fay.kearn@wimborne.co.uk stating which masters you would like.

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For editorial address and phone numbers see page 7



Next Month

Content may be subject to change

Universal Loudspeaker Protector

This *Universal Speaker Protection* module defends your expensive loudspeakers from catastrophic faults in your amplifier. Plus, it mutes switch-on and switch-off thumps, disconnects the speakers if you plug in your headphones and has heatsink temperature sensing in order to control a cooling fan in the amplifier. To cap it all, on-board LEDs indicate the various fault conditions.

9-Channel Infrared Remote Control

Using a tiny, prebuilt 9-button remote, this infrared remote control receiver is ideal for use with TVs, Hi-Fi, audio-visual equipment, model train layouts and even robots! Not only that, but the one tiny handheld remote can be used to control up to three separate receivers, each with seven channels.

Revised USB Charger Regulator with Low Battery Cut-out

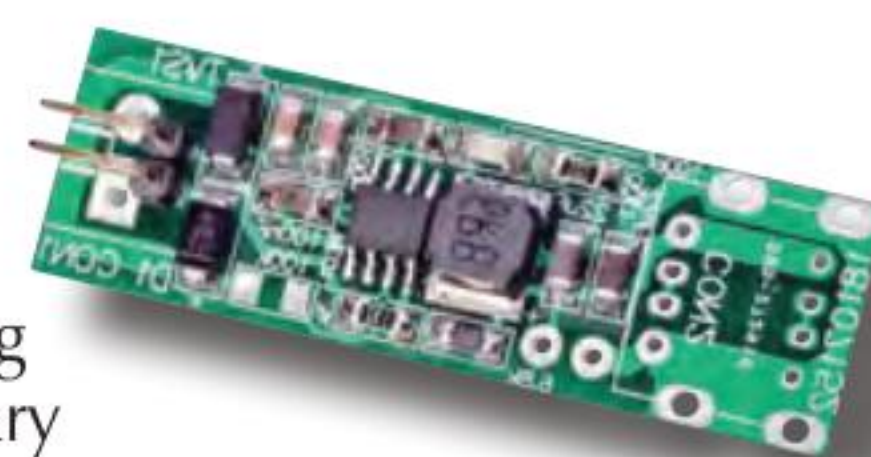
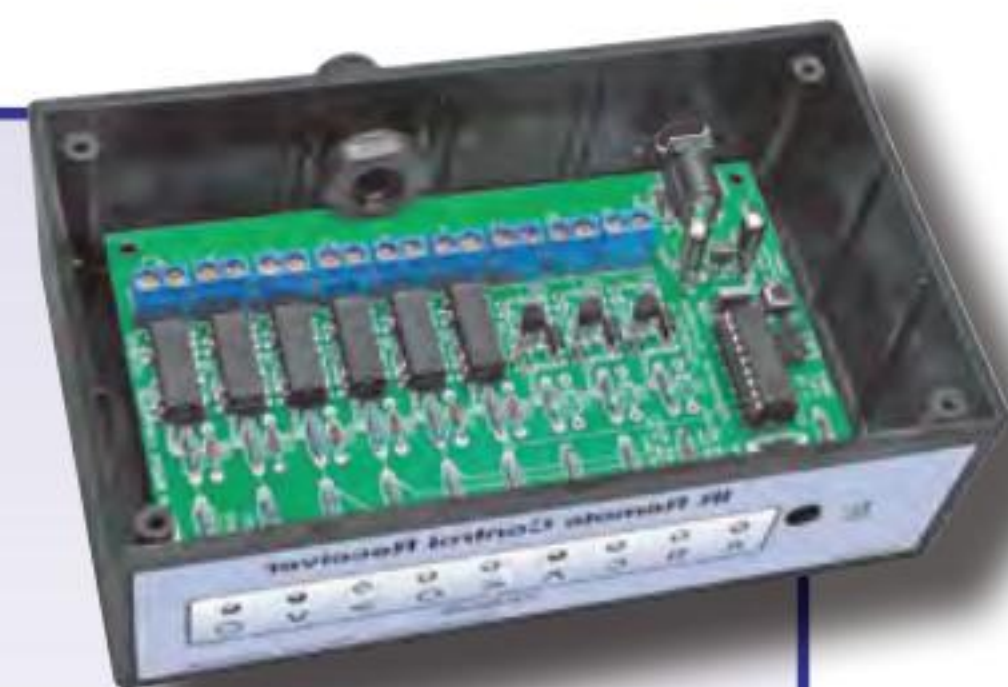
This revised version of our tiny USB charger module now has extra circuitry to prevent any USB device such as a permanently connected dash-camera from discharging the car's battery below 12.15V. We've also boosted the continuous output current from 2.5A to 3A.

Teach-In 2016 – Part 11

In next month's *Teach-In 2016, Arduino World* we will look at Global Positioning System (GPS) modules for use with the Arduino. *Arduino Workshop* will introduce you to practical aspects of using GPS. Our programming feature, *Coding Quickstart*, will show you how to use the Arduino GPS library and our *Get Real* project will be devoted to the design and construction of a simple Arduino-based GPS unit that will display your current longitude and latitude.

PLUS!

All your favourite regular columns from *Audio Out* and *Circuit Surgery* to *Electronic Building Blocks*, *PIC n' Mix* and *Net Work*



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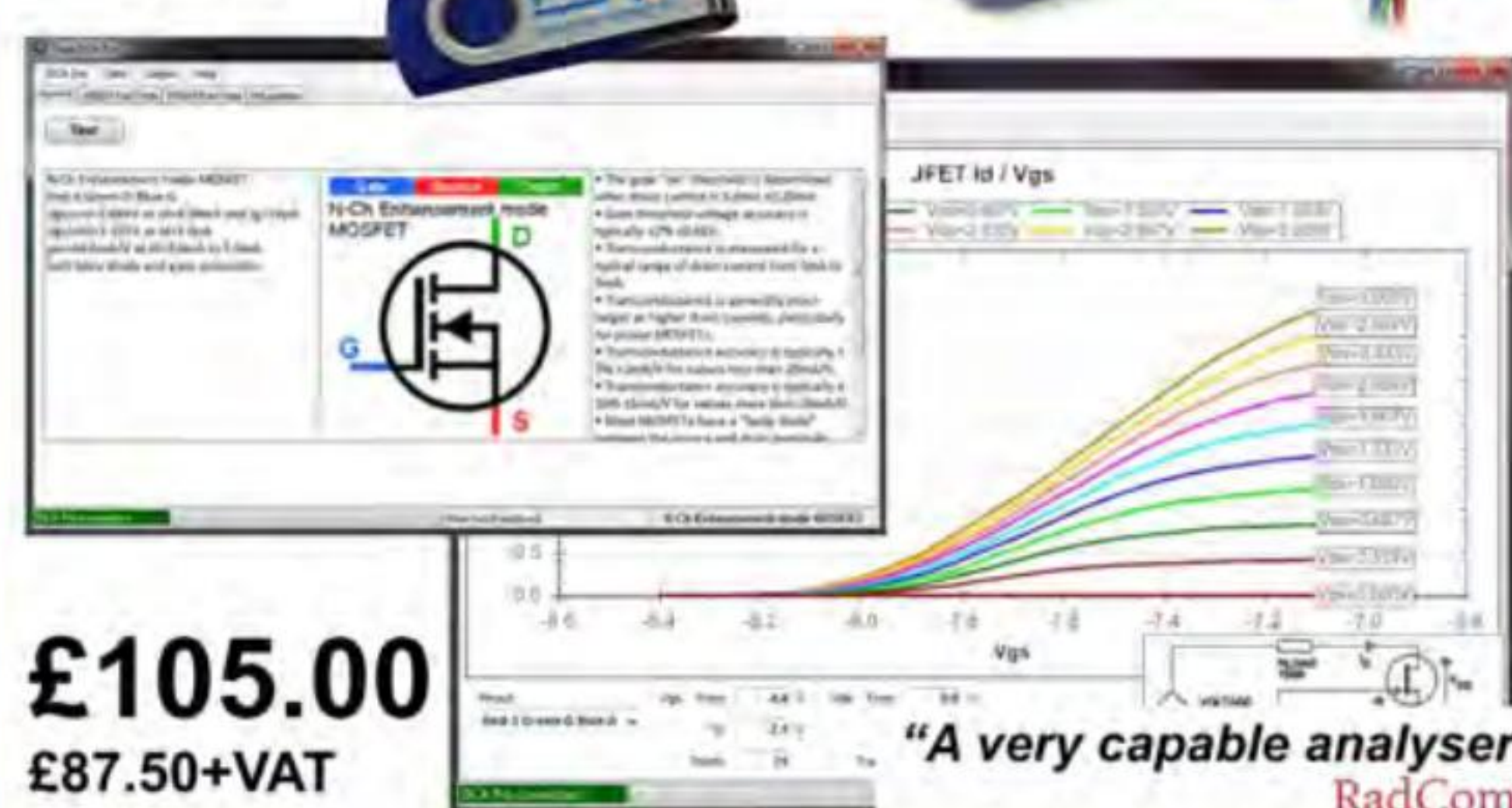
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